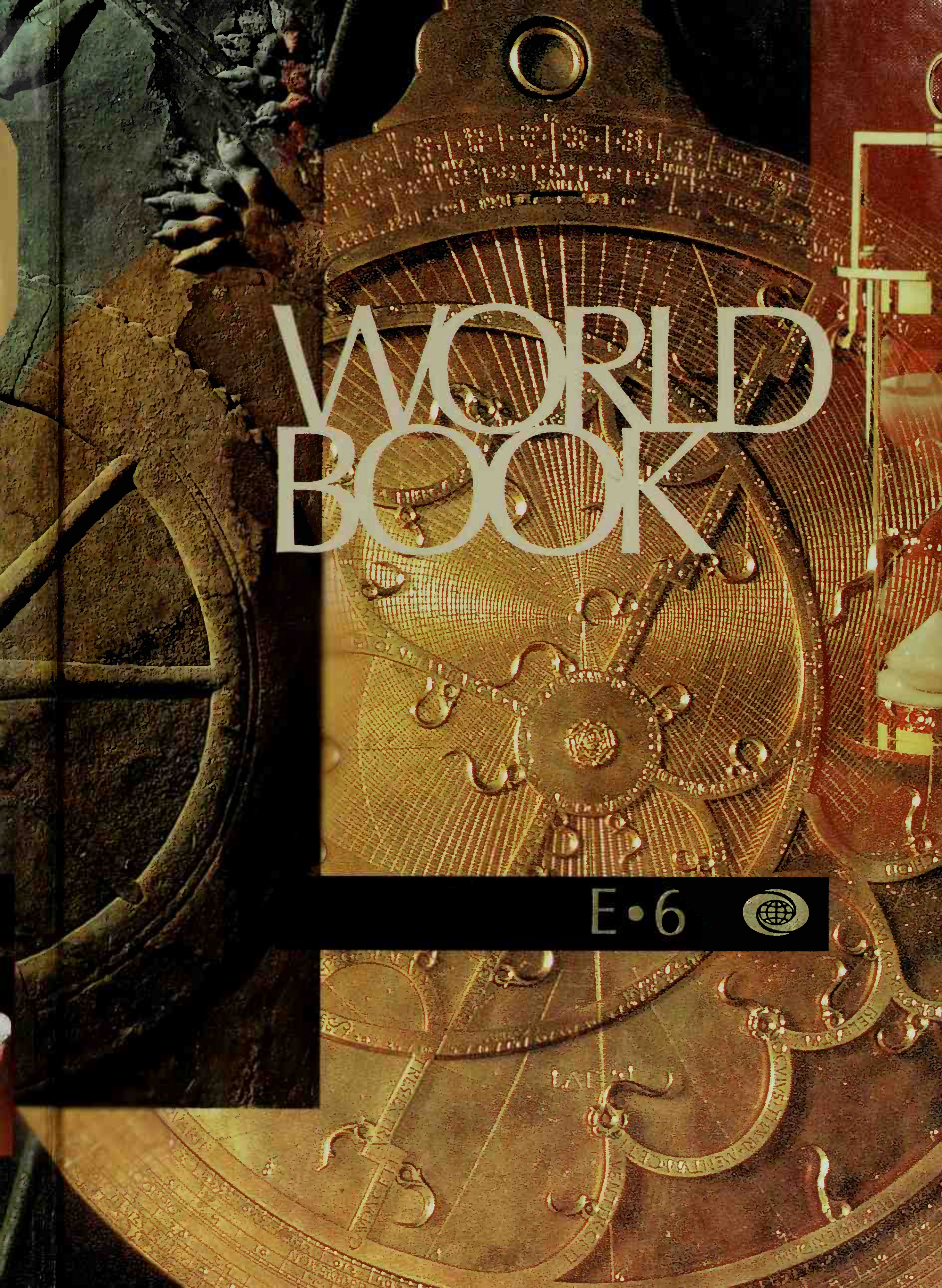

WORLD BOOK

E•6

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Ee

E is the fifth letter of our alphabet. It was also the fifth letter in the alphabet used by the Semites, who once lived in Syria and Palestine. The Semites named the letter *he* and adapted an Egyptian *hieroglyphic* (picture symbol) of a man rejoicing. They did this perhaps because the sound of *he,* which resembles our *h*, began a shout of hallelujah. The ancient Greeks gave the symbol the sound of *e* in *bed.* They called it *epsilon.* The Romans gave the capital E its present form. See **Alphabet.**

Uses. *E* or *e* is the most frequently used letter in books, newspapers, and other printed material in English. On report cards, *E* often signifies *excellent.* It is also an abbreviation for *East.* In *EST,* it stands for *Eastern Standard Time,* and in *E.S.U.,* for *English-Speaking Union.* In music, *e* indicates the third tone in the major scale, as well as the note representing that tone on the staff. In measurements, *e* stands for *erg,* a unit of energy. It stands for *entrance* in stage directions.

Pronunciation. *E* or *e* has various distinct sounds. In English, a person pronounces the long *e* sound, as in *be,* with the highest part of the tongue well forward, toward the hard palate, and with the teeth and lips slightly parted. The other sounds of *e* include that in *bed;* initially, as in *esteem;* and before *r*, as in *fern. E* has a sound of *a* in *sergeant.* In England, this *a* sound occurs often, as in such words as *clerk* and *Derby.* Final *e* is frequently silent, as in such words as *isle* or *quite.* See **Pronunciation.** Marianne Cooley

Development of the letter E

The ancient Egyptians, about 3000 B.C., wrote a symbol that represented a person shouting for joy.

The Semites, about 1500 B.C., used a letter they called *he.* They drew it as a figure of someone shouting.

The Phoenicians included this simple figure in their alphabet about 1000 B.C.

E

The Greeks changed the letter and added it to their alphabet about 600 B.C. They named the letter *epsilon.*

E

The Romans gave the letter E its present form about A.D. 114.

The small letter e first appeared during the A.D. 300's as a rounded letter. By the 500's, the letter had developed its present shape.

A.D. 300

e

500

e

Today

Special ways of expressing the letter E

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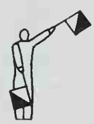
International Morse Code

Braille

International Flag Code



Semaphore Code

Sign Language Alphabet

Common forms of the letter E

Ee *Ee*

Handwritten letters vary from person to person. *Manuscript* (printed) letters, *left,* have simple curves and straight lines. Cursive letters, *right,* have flowing lines.

Ee *Ee*

Roman letters have small finishing strokes called *serifs* that extend from the main strokes. The type face shown above is Baskerville. The italic form appears at the right.

Ee *Ee*

Sans-serif letters are also called *gothic letters.* They have no serifs. The type face shown above is called Futura. The italic form of Futura appears at the right.

E

Computer letters have special shapes. Computers can "read" these letters either optically or by means of the magnetic ink with which the letters may be printed.

E. coli, *EE KOH ly,* is among the most extensively studied bacteria in the history of science. There are hundreds of different strains of this microbe, whose full name is *Escherichia (EHSH uh RIHK ee uh) coli.* Since the mid-1900's, scientists worldwide have used *E. coli* to study basic biological processes, especially the behavior of *genes* (units of heredity).

Outside the laboratory, most strains of *E. coli* live harmlessly in the intestines of people, cattle, and other animals. But *E. coli* can produce serious illness if it causes blood or urinary infections. One recently identified strain, called *E. coli* O157:H7, causes severe intestinal illness. A typical infection with *E. coli* O157:H7 begins with intense abdominal cramps and watery diarrhea that often turns bloody within a few days. Most patients recover in about a week. But the infection can cause damage to the kidneys and *anemia* (low red blood cell count), and a few patients die.

E. coli O157:H7 lives in a small percentage of cattle but does not make them sick. Most infections with *E. coli* O157:H7 are caused by eating undercooked ground beef contaminated with the bacteria. Infections have also been traced to contaminated vegetables and unpasteurized milk and apple cider. Infected people can also pass the illness to others. The best ways to prevent infection are to cook ground meat completely, clean fruits and vegetables thoroughly, and wash hands often.

Anyone with severe or bloody diarrhea should see a doctor promptly to identify the cause and get proper treatment. If tests of several people detect an outbreak of *E. coli* O157:H7, public health officials will take steps to find the source of the illness to prevent infection of other people. David L. Swerdlow

E-commerce, also called *electronic commerce* or *e-business,* is the electronic exchange of money or other valuables for goods and services. The Internet, the worldwide network of computers, enables businesses to participate in e-commerce with other businesses and with consumers.

Business-to-business transactions, also called *B2B transactions,* involve the coordination of purchases and deliveries over the Internet or over a private company-to-company network known as an *extranet.* In a B2B transaction, a manufacturing company might transmit an order for raw materials. The materials provider would, in turn, transmit a bill to the purchaser, who might pay the bill electronically. Only the materials are transported physically. Computers handle everything else.

An e-commerce *trading exchange* is a central Internet site where many buyers and sellers gather electronically. There, multiple suppliers can bid on a company's request. That company can select the bid that best suits its needs and budget, and it can then arrange for purchase and delivery.

Business-to-consumer transactions involve direct sales to individuals. Many businesses operate online stores on the World Wide Web, a system of computer files linked to one another on the Internet. These files include text, pictures, sound, and video. Web-based merchants can present far more products than would be possible in the physical space of a walk-in store. Web merchants deliver some products, such as computer software or data files, to a customer's computer over the Internet. Sellers generally deliver physical products to the purchaser or ship them to a local store, where the purchaser may pick them up.

Most consumers make e-commerce purchases with credit cards or *debit cards,* which deduct purchase costs directly from a bank account. Others use special accounts created solely for electronic purchases. Most e-commerce sales are *secure transactions,* which encode card and purchase information as it leaves the consumer's computer and then decode it for the retailer.

Another popular form of consumer e-commerce is the *online auction,* at which sellers present items for examination by Web shoppers who bid against one another for the right to purchase them. The largest and most popular online auction site is eBay. Online auction sites earn money by charging the seller a small fee or by collecting a portion of the purchase price of items sold.

Banks and government institutions offer many e-commerce services to consumers over the Internet. Consumers can use the Internet to access their accounts, pay bills, and even pay taxes. Keith Ferrell

E-mail, or *electronic mail,* is a message sent from one computer to another over a computer network. E-mail messages can be sent and received over a private network, such as one operated within a company, or over a public network, such as the Internet. A message can consist of text only, or it may include one or more attached files containing text, illustrations, sound clips, or moving pictures.

To send and receive e-mail messages, an individual must have an *e-mail address.* Such an address serves the same function that a street address does for traditional mail delivery. Individuals obtain e-mail addresses from commercial businesses known as Internet service providers (ISP's) or online services. These businesses also supply the computer software needed to compose, send, receive, and read e-mail, and to direct the delivery of customers' e-mail messages.

Files called *electronic mailboxes* store delivered e-mail on a networked computer. To read a message, a user opens the file attached to his or her address. The user can generally respond to the message with the click of a button.

Many people build large mailing lists of the electronic addresses of their friends and business associates. Most e-mail systems enable a user to send the same message to any number of addresses at one time. Keith Ferrell

$E = mc^2$ is an equation developed by the German-born American physicist Albert Einstein that directly relates *mass* (amount of matter) and energy. In the equation, E stands for energy, m stands for mass, and c^2 is the speed of light *squared* (multiplied by itself). The equation shows that large quantities of energy can result from tiny amounts of mass if the mass is completely changed into energy. For example, the conversion of 1 gram produces about 25 million kilowatt-hours of energy.

The equation laid the basis for the application of nuclear energy. When Einstein announced it in 1905, scientists knew of no way to change mass into energy. But during the 1930's, they found a way to split the atoms of certain heavy elements into atoms of lighter elements. The scientists discovered that the total mass of the lighter atoms was less than the mass of the original heavy atom. They also found that energy was produced. They reasoned that when an atom split, the mass that

was lost was changed into energy. Using Einstein's equation, the scientists could calculate how much mass was changed. Richard L. Hilt

See also **Einstein, Albert; Nuclear energy** (Artificial fission).

E Pluribus Unum, *ee PLUR uh buhs YOO nuhm,* is the Latin motto on the face of the Great Seal of the United States (see **Great Seal of the United States**). This phrase means *out of many, one.* It refers to the creation of one nation, the United States, out of 13 colonies. It is equally appropriate to today's federal system. Benjamin Franklin, John Adams, and Thomas Jefferson, members of the first committee for the selection of the seal, suggested the motto in 1776. It can be traced back to Horace's *Epistles.* Since 1873, the law requires that this motto appear on one side of every U.S. coin that is minted.

Critically reviewed by the Department of the Treasury

See also **United States, Government of the** (picture: Symbols of the United States).

Eagle is the name of some of the largest and most powerful birds in the world. Among birds of prey, only condors and some species of vultures are larger than eagles. Eagles look fierce and proud, and they sometimes soar gracefully high in the air. They are often pictured as courageous hunters and have long been symbols of freedom and power. The *golden eagle* best fits this description and is sometimes called "king of birds." But eagles are not always as bold and fierce as they look. Most will eat whatever flesh is easiest to get, including *carrion* (dead animals).

Eagles are careful to avoid danger. They usually stay away from human beings and rarely attack except when cornered. A few species of eagles also may attack when defending their nests and young. An eagle's chief weapons are its powerful legs, feet, and *talons* (claws). Some eagles also bite in self-defense. Eagles may attack newborn lambs or other livestock, but they do so only rarely.

Facts in brief

Names: Adult, eagle; young, eaglet or eyass.
Incubation period: 35-42 days or more, depending on species.
Length of life: 20-50 years.
Where found: Throughout the world, except in Antarctica and where people have killed them off or destroyed their habitat.
Scientific classification: Eagles belong to the class Aves, the order Falconiformes, and the family Accipitridae. Within the family, the larger species are generally called *eagles* and the smaller species *hawks* or *buzzards,* but there is no rigid distinction.

Roman warriors used a golden figure of an eagle as a sign of strength and bravery. Russian and Austrian emperors also used eagles as symbols. The United States chose the *bald eagle* as its national bird in 1782.

The body of an eagle

Eagles vary in size, depending on the species and the individual. Females are generally larger than males. Wingspreads of different species and individuals range from about 4 to 8 feet (1.2 to 2.4 meters). Most eagles weigh about 7 to 12 pounds (3.2 to 5.4 kilograms), but some weigh as much as 20 pounds (9.1 kilograms).

If the wind and other flying conditions are favorable, some species of eagles may be able to carry prey weighing nearly as much as themselves. Normally, however, eagles can only carry smaller prey.

The head of an eagle is large and covered with feathers. An eagle has large eyes that are located on the sides of its head. However, it can see straight ahead. Most birds have keener sight than people and other animals, but eagles and hawks are said to have the keenest sight of all. Eagles can probably sight their prey while soaring high in the air. But they usually watch from perches or fly close to the ground while they are hunting. Eagles have large, strong, hooked beaks, which they use to tear

WORLD BOOK illustration by Stanley W. Galli

A bald eagle, its powerful wings spread wide, returns to its *aerie* (nest) with food for its hungry young. The bald eagle's white head feathers give it the appearance of baldness.

The golden eagle is a feared hunter. Its prey includes rabbits, squirrels, and even young deer and lambs. The golden eagle can carry off prey weighing as much as it does to its nest.

WORLD BOOK illustration by Stanley W. Galli

up their prey. The golden eagle's beak measures about 2 inches (5 centimeters) long and 1 inch (2.5 centimeters) from top to bottom. The bald eagle's beak is even larger.

Feet and legs. Eagles have strong legs and feet. Most eagles have scaly, bright yellow skin on their feet. Eagles seize and kill prey with their long, curved talons. They also use their talons to carry prey to a feeding place. When eagles fight, they dive at each other and try to strike with their talons. The legs of golden eagles and several other species are covered with feathers. The lower part of the bald eagle's legs is bare.

Feathers and wings. Eagles have such long, broad wings and tails that they look clumsy when they are on the ground. But the wings easily support their heavy bodies when they fly. Eagles can glide great distances without flapping their wings. The long feathers in their wings are strong and stiff, and they are shaped so the air flows smoothly over the surface of the wing. When the eagle soars, the feathers spread out like fingers and bend up at the tips.

Most adult eagles are dark brown or black, but many have white areas. Young eagles do not have feathers that match those of their parents until about 4 years of age.

The life of an eagle

Wild eagles that survive to adulthood are thought to live from 20 to 30 years. In captivity, eagles may live 50 years or more. Most eagles first breed when they are about 5 years old. Mated eagles are thought to stay together. If one member of a pair dies, the other may find another mate. In winter, bald eagles may gather in areas with plentiful food. But during the breeding season, each pair claims a territory around its nest and keeps other eagles away. The golden eagle may defend a territory of about 20 to 60 square miles (50 to 160 square kilometers). The bald eagle holds a smaller territory.

Nests of eagles are called *aeries* or *eyries* (both pronounced *AIR eez* or *IHR eez*). Bald eagles usually build their aeries in the tops of tall trees that are near water. Some nest on cliffs. Golden eagles usually nest on high cliffs in the mountains. Some eagles in Asia nest on the ground. Eagles tend to use the same aerie every year. However, some eagles have two or more aeries. They use one aerie one year and another the next year.

Eagles build aeries mainly with sticks. They often decorate the aerie with fresh leaves while they are using it. They usually add new material each year they use an aerie, so many old aeries are very big. A new aerie may be 6 feet (1.8 meters) across and 18 inches (46 centimeters) deep. But an old aerie may be up to 10 feet (3 meters) across and 15 feet (4.5 meters) deep.

Eggs are about 3 inches (7.6 centimeters) long and 2 inches (5 centimeters) across. Females lay one, two, or—rarely—three eggs each year. The eggs of golden eagles are white or spotted with reddish-brown or gray. The eggs of bald eagles are white and become stained with yellow in the nest. Northern eagles lay eggs in March. Bald eagles in Florida lay eggs during the fall and winter.

The eggs hatch in five to six weeks or more, depending on the species. In that time, the female *incubates* the eggs—that is, she sits on them to keep them warm. The male incubates them occasionally, and brings food to the female while she sits. After the eggs hatch, both parents guard the nest and take food to the young.

Young eagles are called *eaglets* or *eyasses*. Eaglets are hatched with their eyes open. They are covered with

a grayish-white *down* (fuzz). Their regular feathers begin to grow when they are 2 to 3 weeks old. Eaglets are not able to tear up their own food until they are 6 or 8 weeks old. They leave the nest when they are 11 to 12 weeks old, but they cannot fly very well at first. They stay near the aerie for several weeks. The parents feed them for a few more months until they can hunt well enough to get their own food.

Some species of eagles hatch two eggs. But it is unusual for both eaglets to survive. One usually hatches two or three days before the other. The older eaglet is larger and takes more than its share of food. It also attacks the smaller eaglet repeatedly and may kill it.

Food. Eagles hunt only during the day. They spend the night in their aeries or on a safe perch. Often, two eagles hunt together. Some eagles eat only certain types of prey. But most hunt a wide variety of prey and occasionally eat carrion or steal prey from other animals.

The golden eagle eats rabbits, hares, ground squirrels, and birds. Sometimes it eats young deer and lambs, and it may also eat carrion. The golden eagle usually flies low over open hillsides, dropping down quickly to seize its startled prey.

The bald eagle eats mainly fish. It finds schools of fish by following other fish-eating birds. It snatches fish from the water while flying. A bald eagle can swim to shore with its catch by floating and using a rowing motion with its wings. It sometimes takes fish away from other birds, such as gulls and ospreys. Occasionally, bald eagles catch coots and other water birds by hovering over them and forcing them to dive repeatedly until they are exhausted. In addition, they sometimes catch birds in the air with spectacular aerial maneuvering. Bald eagles also capture mammals and sometimes eat carrion.

Kinds of eagles

There are about 60 species of eagles. Most of them are native to tropical regions, particularly in Africa and Asia. Only two species, the bald eagle and golden eagle, are native to the continental United States and Canada.

The bald eagle is not really bald. Its head is covered with white feathers. Its tail is also white. A young bald eagle is dark brown and has scattered light markings. The bald eagle is found only in North America and is the national bird of the United States.

Until the mid-1900's, hunters and trappers killed many bald eagles. The species has been protected by federal law since 1940 in the lower 48 states and since 1953 in Alaska. But the continued loss of wilderness regions to agriculture and urban development caused a further decline in bald eagle populations. The number of bald eagles also dropped because of the pollution of lakes and rivers with pesticides and industrial wastes. Some of these pollutants built up in the bodies of fish that the eagles ate. In most cases, the pollutants did not kill the birds, but they interfered with the birds' ability to reproduce. By the mid-1970's, there were only about 2,000 to 3,000 bald eagles making nests in the lower 48 states.

Since then, however, the bald eagle has made a gradual comeback. The U.S. government has banned certain pesticides and tightened controls on other pollutants. Conservation groups have restocked former nesting areas with young eagles. Bald eagles also have become more accustomed to people and now often nest in non-wilderness areas close to human activity. Today, there are about 20,000 bald eagles in the lower 48 states, and an estimated 85,000 in Canada and Alaska.

The golden eagle is dark brown with a patch of golden brown feathers on the back of its neck. A young golden eagle is dark with white patches on its wings and tail. Golden eagles live in Europe, Asia, northern Africa, and much of North America. Plains Indians once used golden eagle feathers in their bonnets, and the golden eagle became known as the "war eagle." Some golden eagles migrate south to spend the winter in the southwestern United States and Mexico. Many golden eagles have been killed in California, Colorado, Wyoming, and Texas by sheep ranchers who feared the birds would kill young lambs. In Texas, thousands were shot from airplanes by hired hunters. The golden eagle has been protected by federal law since 1962. But some are still being killed illegally.

Other kinds of eagles include two species that sometimes stray to North America but do not breed there. They are the *white-tailed eagle* and *Steller's sea eagle.* Both are closely related to the bald eagle and have similar habits. The white-tailed eagle breeds in many parts of Asia and the European mainland, and in Iceland and Greenland. It has a white tail like the bald eagle, but its head is dark. Steller's sea eagle is dark, except for a white tail and white shoulders. It is one of the largest and most powerful of all eagles. It breeds on the Pacific coast of Siberia and in Korea, and sometimes visits the Aleutian Islands near Alaska.

The *harpy eagle* of tropical South America is another of the world's largest and strongest eagles. It lives in the dense rain forests. The harpy eagle preys on capuchin monkeys, sloths, and other mammals. It is black and white with a gray head and a long, black crest. The harpy eagle raises one eaglet at a time, and feeds it for nearly a year after it is hatched. The parents probably breed only one time every two years. See **Harpy eagle**.

The *Philippine eagle,* found only in the Philippines, looks much like the harpy eagle and lives in much the same way. It eats monkeys and other mammals, and large birds and reptiles. It builds its nest in giant trees in the rain forests. These eagles are becoming scarce because many are shot, and the rain forests they live in are being cut down. The *crowned eagle* of Africa also lives in the rain forests and eats monkeys.

The *martial eagle,* another of the largest eagles, lives in the grassy plains of Africa and eats *hyraxes* (small animals related to elephants), as well as a variety of other animals. The *African fish eagle* is related to the bald eagle. The African fish eagle lives beside lakes and rivers. This kind of eagle makes a wild, screaming call with its head turned far back over its shoulders.

The *white-bellied sea eagle* of southern Asia and Australia is a gray and white bird that lives on tropical coasts. It eats fish and sea snakes, snatching them from the sea with its talons. The *serpent eagle* of Asia lives in the tops of tall trees. It eats snakes and lizards. The *steppe eagle* of central Asia lives on treeless plains. It sometimes nests on the ground. The steppe eagle and other types of eagles migrate to Africa each winter. Great flocks of them fly over the Egyptian deserts every spring and fall. James W. Grier

See also **Bird** (pictures: Birds of the desert).

Eagle was the popular name for a $10 gold coin minted in the United States between 1795 and 1933. The coin was not minted from 1805 to 1837. It was one of three coins named in 1792 in the first act of Congress to authorize coinage. For many years it was the highest denomination of any U.S. coin. Eagles were used widely in the United States until 1934, along with double-eagles, half-eagles, and quarter-eagles. In 1933, a law was passed to take all gold coins out of circulation. In 1986, however, the U.S. Mint began selling gold bullion coins, called American Eagles, to investors. The U.S. Mint also makes some commemorative coins from gold. The Mint began offering platinum bullion coins, called Platinum Eagles, in 1997. Burton H. Hobson

See also **Money** (The first United States currency).

Eagles, Fraternal Order of, is a benefit-paying fraternal organization. It has more than a million members in about 1,900 *Aeries* (chapters) in the United States and Canada. Women in about 1,700 auxiliary chapters are active in the national, state, and local programs. Major programs aid children with mental retardation and senior citizens and support research on Alzheimer's disease, cancer, diabetes, the heart, and kidney disease. The order promotes state old-age pensions, social security legislation, Mother's Day observances, health research, civic activities, and legislation banning job bias against older workers. In cooperation with CARE, the Fraternal Order of Eagles has set up 17 youth training centers in Mexico and in European, South American, and Near and Far Eastern countries. The order was founded in Seattle, Washington, in 1898. Its informal slogan is *Eagles Are People Helping People.* Its offices are in Brookfield, Wisconsin. Critically reviewed by the Fraternal Order of Eagles

Eagleton, Thomas Francis (1929-), became the only man ever nominated by a national convention for vice president of the United States who resigned his candidacy. In 1972, the Democratic National Convention chose Eagleton, a U.S. senator from Missouri, as the running mate of Senator George S. McGovern of South Dakota. Twelve days later, Eagleton revealed that he had been hospitalized three times between 1960 and 1966 for treatment of emotional exhaustion and depression.

Eagleton was born in St. Louis. He graduated from Amherst College in 1950 and Harvard Law School in 1953. Eagleton was elected circuit attorney of St. Louis in 1956, attorney general of Missouri in 1960, and lieutenant governor in 1964. He served in the United States Senate from 1969 to 1987. David S. Broder

Eakins, *AY kihnz,* **Thomas** (1844-1916), was one of the greatest American realist painters of the 1800's. He painted portraits and many scenes of outdoor life and sporting events, such as swimming, sculling, hunting, and prize fighting. Eakins brought great vitality and deep human insight to his art. He tried to achieve scientific accuracy and painstaking detail without losing feeling. The colors are fairly dark in his indoor paintings and portraits, but he captured the subtle effects of light and atmosphere in his outdoor scenes.

His most famous portraits include *Walt Whitman, The Thinker,* and two group portraits, *The Clinic of Dr. Gross* and *The Clinic of Dr. Agnew.* Among his famous outdoor paintings is *Max Schmitt in a Single Scull.*

Eakins was born in Philadelphia. He began his art training at the Pennsylvania Academy of Fine Arts, and studied anatomy at Jefferson Medical College in Philadelphia. In 1866, he went to Paris to study at the École des Beaux-Arts, where he stayed three years. He then spent several months in Spain. When he returned to the United States in 1870, he established himself as a portrait painter in Philadelphia. But he did not gain widespread public or critical acceptance. He taught at the Philadelphia Academy and lectured on anatomy at other art schools. Eakins helped develop photographic techniques for studying the human body in motion. He was also a sculptor. Sarah Burns

See also **Whitman, Walt** (picture).

Eames, *eemz,* **Charles** (1907-1978), was an American designer who became internationally famous for creating some of the most imaginative furniture of the 1900's. Eames was especially noted for his skillful use of plywood and plastic to create comfortable, practical, and inexpensive chairs of high quality. Some of his most influential designs are still used in homes and offices worldwide.

In 1946, Eames introduced the most famous of his *Eames chair* designs. It consisted of a molded plywood seat and back that seemed to float on a thin metal frame (see **Furniture** [Recent developments; picture: Classics of modern furniture design]). Eames's *stacking chairs* have molded fiberglass bodies and aluminum legs. They can be stacked one on top of another for storage. His other designs include a lounge chair made of molded plywood on a metal pivot base and a chair with four wire legs supporting a molded plastic shell.

Eames was born in St. Louis. He also designed houses, museum exhibits, and toys. Nancy E. Richards

Philadelphia Museum of Art

Thomas Eakins became noted for his pictures of sports events, such as *Between Rounds,* shown here, painted in 1899.

Ear

Ear is the sense organ that makes it possible for us to hear. Hearing is one of our most important senses. It enables us to communicate with one another through speech. The development of speech itself depends mostly on hearing. Children learn to talk by listening to and imitating the speech of other people. Hearing can also alert us to danger. We hear the warning honk of an automobile horn or the whistle of an approaching train. Even while asleep, we may hear a fire alarm or the barking of a watchdog. In addition, hearing provides pleasure. For example, it enables us to enjoy music, the singing of birds, and the sound of the surf.

Hearing is a complicated process. Everything that moves makes a sound. Sound consists of vibrations that travel in waves. Sound waves enter the ear and are changed into nerve signals that are sent to the brain. The brain interprets the signals as sounds.

Besides enabling us to hear, our ears help us keep our balance. The ears have certain organs that respond to movements of the head. These organs inform the brain about any changes in the position of the head. The brain then sends messages to various muscles that keep our head and body steady as we stand, sit, walk, or move in any way.

Many kinds of animals have ears similar to those of human beings, and some have an extremely keen sense of hearing. Hearing is vital to the safety and survival of numerous animals. Sounds may warn them of approaching enemies or other dangers. In addition, many animals sing, growl, hiss, or make other sounds and depend partly on their sense of hearing to communicate with one another.

This article deals mainly with the human ear. It describes the parts of the ear, the sense of hearing, and the sense of balance. It also discusses disorders of the ear. The last section of the article describes some of the differences in the ears of various kinds of animals.

Parts of the ear

Human beings have an ear on each side of the head. The ears extend deep into the skull. Each ear has three main parts: (1) the outer ear, (2) the middle ear, and (3) the inner ear.

The outer ear consists of two parts. They are (1) the auricle and (2) the external auditory canal.

The auricle is the fleshy, curved part of the ear on the outside of the head. The auricle has no bone. It consists mainly of tough, elastic tissue called *cartilage,* which is covered by a thin layer of skin. The loosely hanging lower part of the auricle is called the *earlobe.* It is made up of fat.

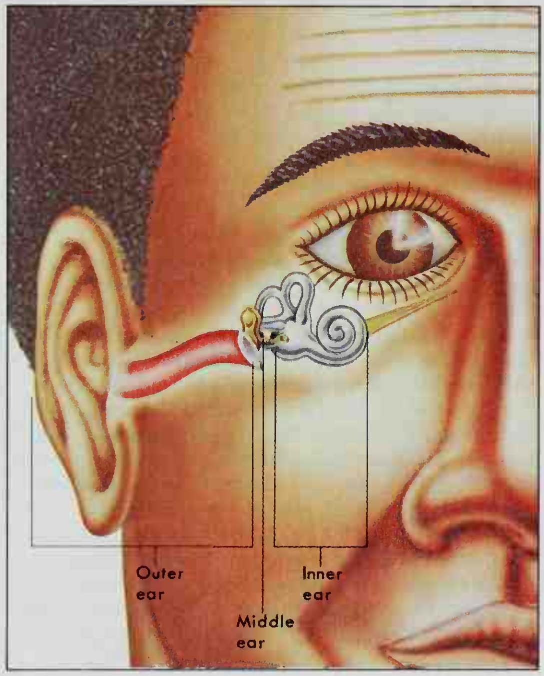
Three small muscles attach the auricle to the head. In human beings, these muscles have no practical use. However, some people can move them and so wiggle their ears. In many animals, these muscles are well developed and highly movable. Cats, dogs, foxes, horses, rabbits, and many other animals can turn their ears in the direction from which a sound is coming and so improve their hearing.

The external auditory canal is the opening you see if you look directly into the ear. This passageway leads to the *eardrum,* also called the *tympanic membrane.* The eardrum separates the outer ear from the middle ear. It is a thin, round, tightly stretched membrane about $\frac{2}{5}$ inch (10 millimeters) in diameter.

The external auditory canal is about 1 inch (2.5 centimeters) long. It curves somewhat in the shape of a *C.* The canal is lined with skin. The skin on the outer third of the canal has hairs, sweat glands, and glands that produce earwax. Earwax helps protect the eardrum by trapping dirt that would otherwise lodge against the membrane. Sometimes, earwax builds up in the canal and must be removed by a doctor. Never try to remove earwax yourself, especially by sticking small objects into the ear. You could easily puncture the eardrum.

The inner two-thirds of the auditory canal is surrounded by the *temporal bone,* which is the hardest bone in the body. The temporal bone also surrounds the middle ear and the inner ear. The bone protects the delicate structures of these parts of the ear.

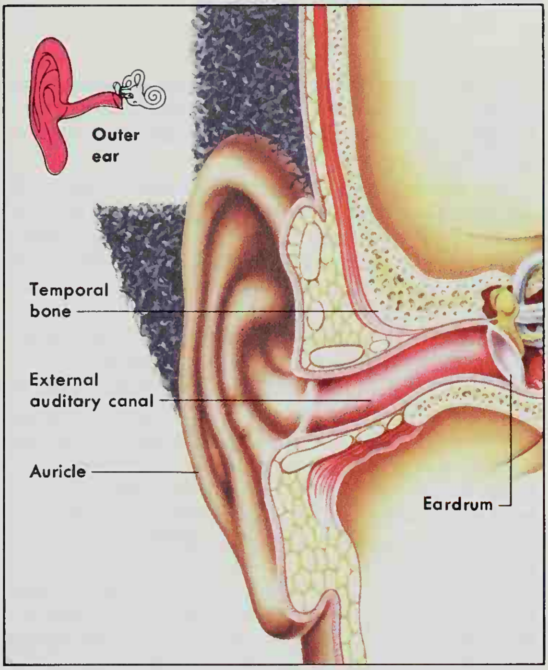
The middle ear is a small chamber behind the eardrum. Three bones called the *auditory ossicles* extend across the chamber. The bones are linked together and connect the eardrum to the inner ear. The three bones have the Latin names *malleus,* which means *hammer;*



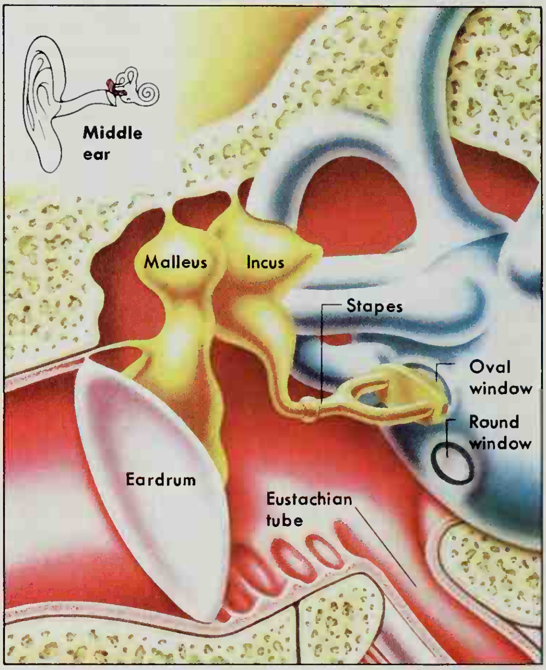
WORLD BOOK illustration by Colin Bidgood

The human ear extends deep into the skull. Its main parts are (1) the outer ear, (2) the middle ear, and (3) the inner ear.

The contributors of this article are David D. Caldarelli, Professor and Chairman of the Department of Otolaryngology and Bronchoesophagology at Rush-Presbyterian-St. Luke's Medical Center in Chicago; and Ruth S. Campanella, Assistant Professor in the department.



The outer ear consists of the *auricle,* the fleshy part of the ear on the side of the head, and the *external auditory canal,* a passageway that leads to the *eardrum.* The inner two-thirds of the auditory canal is surrounded by the *temporal bone.*



WORLD BOOK illustrations by Colin Bidgood

The middle ear has three bones—the *malleus, incus,* and *stapes.* They link the eardrum to the *oval window,* a membrane of the inner ear. The *Eustachian tube* leads from the middle ear to the back of the throat.

incus, which means *anvil;* and *stapes,* which means *stirrup.* The bones look somewhat like the objects for which they are named. The malleus is the largest auditory ossicle. One end of the bone is attached to the eardrum, and the other end is joined to the incus. The incus, the second largest ossicle, connects the malleus to the stapes. The stapes is the smallest bone in the body. It is tinier than a grain of rice. The footplate of the stapes is attached to a membrane called the *oval window,* which leads to the inner ear.

A narrow tube called the *Eustachian tube* connects the middle ear to the back of the throat. The tube is collapsed most of the time. It opens when you open your mouth, yawn, swallow, or blow your nose. When the Eustachian tube opens, air passes between the middle ear and the throat and so makes the air pressure on the inner side of the eardrum equal that on the outer side. If the Eustachian tube did not open, the eardrum would rupture when the air pressure, which varies with altitude, changes suddenly. The air pressure outside the eardrum changes rapidly, for example, when you go up or down quickly in an elevator or land or take off in an airplane. In such cases, you have the sensation of "popping" of the ears as the Eustachian tube opens and allows air to escape from or to enter the middle ear.

The inner ear has many delicate, interconnected structures and is sometimes called the *labyrinth.* A labyrinth is a group of passageways with a complicated arrangement. The inner ear consists of a *bony labyrinth* that encloses a narrower *membranous labyrinth.* A special kind of fluid separates the bony labyrinth from the membranous labyrinth.

The inner ear has three basic parts, which are connected. They are (1) the vestibule, (2) the semicircular canals, and (3) the cochlea.

The vestibule is a small, round chamber about $\frac{1}{5}$ inch (5 millimeters) long. It forms the central part of the inner ear. Its bony walls connect the semicircular canals and the cochlea. Two *sacs* (baglike structures) lie within the vestibule. These sacs are called the *utricle* and the *saccule.* The inner wall of each sac has a swelling lined with *hair cells.* Hair cells are specialized sense cells with tiny, hairlike projections. The hair cells are attached to nerve fibers. A delicate membrane lies above the hair cells. Small mineral grains called *otoliths* are embedded in the membrane.

The vestibule has two small membranes that face the middle ear. One is the oval window, which is attached to the footplate of the stapes. The other is the *round window,* which lies just below the oval window.

The semicircular canals are behind the vestibule. They consist of three canals set at right angles to one another. They are called the *lateral, superior,* and *posterior* canals. The lateral canal is horizontal. The two other canals are vertical. The superior canal lies in front of the posterior canal. Each canal forms two-thirds of a circle.

Each semicircular canal contains a fluid-filled *duct* (tube). One end of each duct widens and forms a pouch. This pouch, called the *ampulla,* has hair cells that are attached to nerve fibers.

The ducts of the semicircular canals are joined to the utricle. The utricle, in turn, is connected by a duct to the saccule. The semicircular canals and the utricle and saccule make up the ear's organs of balance. They are

sometimes called the *vestibular organs* or the *labyrinthine organs.*

The cochlea is in front of the vestibule. It resembles a snail shell and forms a spiral that coils $2\frac{1}{2}$ times around its tip. Three fluid-filled ducts wind through the cochlea. One begins at the oval window, and another at the round window. These two ducts join at the tip of the spiral. The third duct, called the *cochlear duct,* lies between the first two. One wall of the cochlear duct consists of the *basilar membrane.* This membrane has over 15,000 hair cells. The hair cells make up the *organ of Corti,* which is the actual organ of hearing. A membrane called the *tectorial membrane* lies above the hair cells.

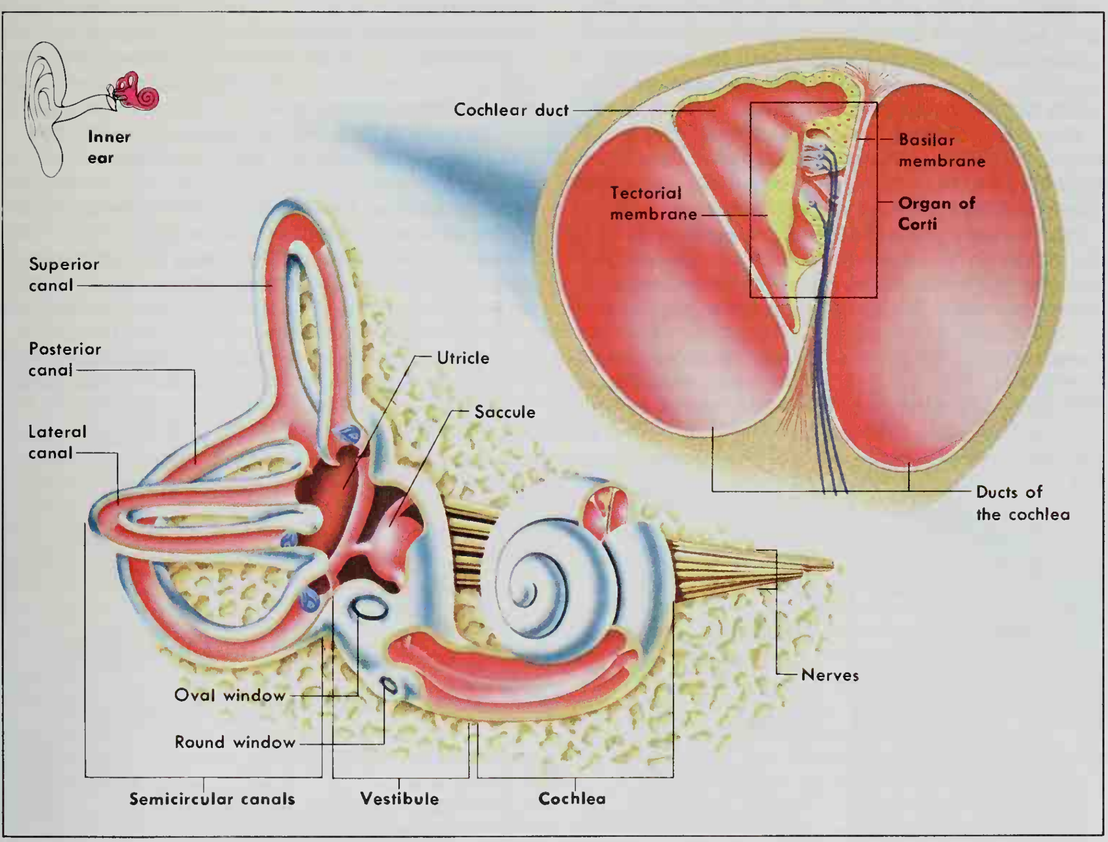
The nerve of the inner ear is known as the *auditory nerve.* It has two branches—the *cochlear nerve* and the *vestibular nerve.* Fibers of the cochlear nerve extend to each hair cell of the organ of Corti. Some fibers of the vestibular nerve lead to the hair cells of the utricle and the saccule, and others extend to the hair cells of the ampulla of each semicircular canal.

The sense of hearing

Sound consists of vibrations that travel in waves through the air, the ground, or some other substance or surface. Sounds vary in *frequency* and *intensity.* Frequency is the number of vibrations produced per second and is measured in *hertz.* One vibration per second equals 1 hertz. A high-frequency sound has a high pitch, and a low-frequency sound has a low pitch. The full range of normal human hearing extends from 20 to 20,000 hertz. As a person grows older, however, the ability to hear high-frequency sounds decreases. Intensity is the amount of energy in a sound wave. It is measured in *decibels.* A person can barely hear a sound of zero decibels. Sounds above 140 decibels can be painful to the ears. In some cases, they may seriously damage the ears.

This section describes (1) how sounds travel to the inner ear and (2) how sounds reach the brain.

How sounds travel to the inner ear. Sound waves enter the external auditory canal of the outer ear and strike the eardrum, causing it to vibrate. The vibrations from the eardrum then flow across the three auditory ossicles of the middle ear—from the malleus, which is attached to the eardrum, to the incus and then to the stapes. The footplate of the stapes vibrates within the oval window, which lies between the middle and inner ears. These movements of the footplate create waves



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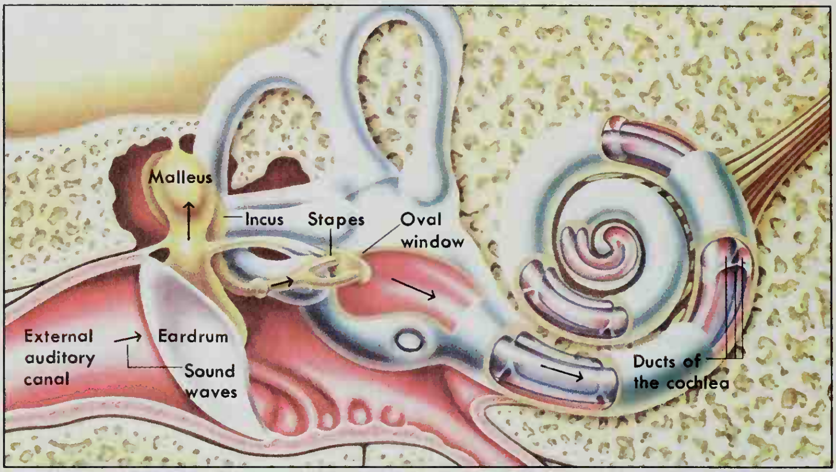
The inner ear consists of the *vestibule, semicircular canals,* and *cochlea.* The vestibule includes the *utricle* and *saccule,* which with the semicircular canals form the ear's organs of balance. The cochlea has three fluid-filled ducts, shown enlarged at the right above. One wall of the central *cochlear duct* is formed by the *basilar membrane,* which has many hair cells. The hair cells make up the *organ of Corti,* the actual organ of hearing. The *tectorial membrane* lies above the hair cells.

How sounds travel to the inner ear

Sound waves enter the ear through the external auditory canal. They strike the eardrum, causing it to vibrate. The vibrations flow across the malleus, incus, and stapes. The footplate of the stapes vibrates within the oval window, creating waves in the fluid that fills the ducts of the cochlea.



WORLD BOOK illustration by Colin Bidgood

in the fluid that fills the ducts of the cochlea of the inner ear.

Besides transmitting sound waves to the oval window, the auditory ossicles of the middle ear *amplify* (strengthen) the waves. Sound waves do not travel as easily through the cochlear fluid of the inner ear as they do through the air. They diminish by about 30 decibels as they pass through the cochlear fluid. But amplification of the sound waves by the auditory ossicles makes up for the loss in intensity.

Sound waves can also be conducted to the inner ear through the bones of the skull. This process is called *bone conduction.* Some of the sound produced by your voice travels to your inner ears in this way.

How sounds reach the brain. The movements of the footplate of the stapes in the oval window produce waves in the cochlear fluid. The cochlear fluid pushes against the basilar membrane, causing it to move. The hair cells of the organ of Corti on the basilar membrane slide against the overhanging tectorial membrane. The hairs bend and so create impulses in the cochlear nerve fibers attached to the hairs. The cochlear nerve transmits the impulses to the *temporal lobe,* the hearing center of the brain. The brain interprets the impulses as sounds. See **Brain** (In receiving sensory messages).

Sounds of high, middle, and low frequency affect hair cells at different locations along the basilar membrane. High-frequency sounds move hair cells near the base of the spiraling cochlea. Middle-frequency sounds move hair cells near the middle of the spiral, and low-frequency sounds affect those near the top. The nerve fibers of the basilar membrane also send impulses of the same frequency as that of a particular sound.

The intensity of a sound determines how many hair cells are affected and how many impulses the cochlear nerve sends to the brain. For example, loud sounds

How the ear changes sounds into nerve impulses

The waves in the fluid that fills the ducts of the cochlea, *below left,* push against the basilar membrane. The hair cells of the organ of Corti on the basilar membrane slide against the overhanging tectorial membrane, *below right.* The hairs bend and so create impulses in the cochlear nerve fibers attached to the hairs. The cochlear nerve transmits the impulses to the brain.

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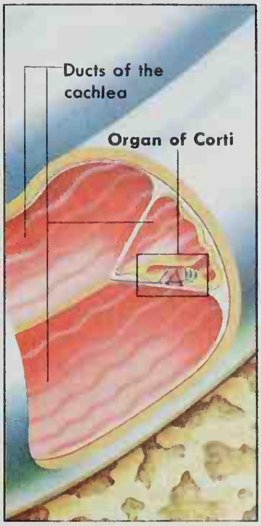
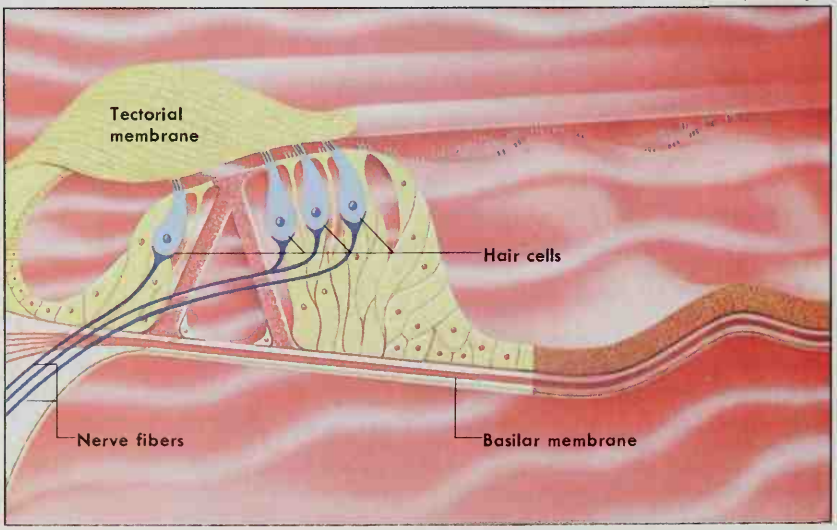




move a large number of hair cells, and the cochlear nerve transmits many impulses.

A person's ability to tell the direction from which a sound comes depends on *binaural hearing*—that is, hearing with both ears. For example, a sound coming from the right side of a person reaches the right ear a fraction of a second sooner than it reaches the left ear. The sound is also slightly louder in the right ear. The brain recognizes this tiny difference in time and loudness and so determines the direction from which the sound came.

The sense of balance

Most people are less aware of the sense of balance than they are of hearing, vision, and other senses. But without a sense of balance, we could not hold our body steady, and we would stagger and fall when we tried to move.

The brain's response to information from various sense organs keeps the body balanced. The vestibular organs—that is, the semicircular canals, utricle, and saccule—inform the brain about changes in the position of the head. The eyes and certain pressure-sensitive cells in the limbs and other parts of the body also inform the brain about changes in the position of the body. The brain then coordinates movements of various muscles that keep the head and body steady. These muscle movements occur automatically and are therefore called *reflex actions.*

This section describes (1) how the semicircular canals respond to movement, (2) how the utricle and saccule respond to gravity, and (3) disturbances of the organs of balance.

The response to movement. The semicircular canals respond to changes in the angle of the head, as by turning, tilting, or bending. Such movements cause the fluid in the ducts of the canals to flow in a certain direction.

Different types of movements affect different canals. Turning the head, for example, affects the lateral, or horizontal, canal in each ear. The fluid moves in opposite directions in the ducts of the two canals. In one ear, the movement of the fluid stimulates the hair cells in the ampulla, the pouch at the end of the duct. The nerve fibers attached to the hair cells then send an increased number of impulses to the brain by way of the vestibular nerve. In the other ear, the movement of fluid has the opposite effect, and the vestibular nerve sends fewer impulses to the brain. If you turn your head to the left, for example, the impulses to the brain from the left ear increase, and those from the right ear decrease. The brain determines which way the head has turned by the difference in the number of impulses from the two ears.

When the head is stationary, the canals in both ears send the same number of nerve impulses to the brain. The brain then recognizes that the head is stationary.

The response to gravity. The utricle and saccule react to the pull of gravity. They work by means of the otoliths, the small mineral grains embedded in a membrane above the hair cells within the organs. The vestibular nerve fibers attached to the hair cells are stimulated when the otoliths press against the hair cells. The force with which the otoliths press against the hair cells depends on the strength of the pull of gravity. The vestibular nerve sends this information to the brain. The brain's response maintains the body's posture.

The utricle and saccule do not work under conditions of zero gravity, which occur in outer space. But the semicircular canals do function under zero gravity.

Disturbances of the organs of balance may make it difficult for a person to hold the head and body erect. If the vestibular organs are damaged or diseased, they send too many or too few impulses to the brain. The brain interprets these abnormal messages as an imbalance of the body. The person then has a false feeling of motion, or dizziness. This condition is also called *vertigo.* A person whose vestibular organs have been destroyed may gradually learn to depend entirely on eyesight and other senses to maintain balance.

Some people suffer from *motion sickness* when they travel by boat, automobile, train, or airplane or when they whirl about rapidly. The symptoms of motion sickness include vertigo, nausea, and vomiting. Motion sickness is caused by excessive stimulation of the vestibular organs. But researchers do not know why some people develop motion sickness more easily than others do. See **Motion sickness**.

Disorders of the ear

Disorders of the ear may result in hearing loss. Some disorders may also affect the sense of balance. The causes of ear disorders are (1) birth defects, (2) injuries, and (3) diseases.

Birth defects. Some children are born without outer ears or with deformed outer ears. The eardrum and auditory ossicles may also be absent or deformed. In certain cases, such defects can be corrected by surgery. Surgeons may construct outer ears with tissues from other parts of the child's body. They may insert artificial ossicles made of plastic or wire or transplant healthy ossicles from a person who has died. Some children are born without inner ears or with poorly developed inner ears. Defects of the inner ears cannot be repaired. In many cases, a child born with defects of the ears also has defects in other parts of the body.

About 30 to 40 percent of all cases of birth defects of the ears are inherited. In some other cases, a disease that a woman contracts during pregnancy may damage the ears of her child. For example, a woman who has rubella during the first three months of pregnancy may give birth to a child with defective inner ears. A condition called *erythroblastosis fetalis* can also damage a baby's auditory system. In this condition, the blood of the unborn child contains a substance called the *Rh factor,* which is not in the expectant mother's blood. The mother's body produces substances that attack the Rh factor. The reaction may damage the child's inner ear and auditory nerve. However, most cases of erythroblastosis fetalis can be prevented. See **Rh factor**.

Certain drugs that a woman might take during pregnancy can prevent the normal development of the baby's cochlea or auditory nerve. A baby's ears may also be damaged if the child experiences head injuries, a lack of oxygen, or some other shock during or immediately after birth.

Newborn babies suspected of having a severe hearing loss should have their hearing tested within a few days after birth. Many deaf children can learn to speak

and to read lips. But to do so, they need training at an early age. Children with a mild hearing loss can be fitted with hearing aids.

Injuries. Blows to the head, severe burns about the head, and other head injuries can damage the outer, middle, or inner ear. In some cases, the injuries may cause temporary hearing loss. In other cases, the loss may be permanent.

Sudden pressure changes can damage the ears and cause hearing loss. Scuba divers, for example, are exposed to changes in water pressure as they dive to great depths underwater and return to the surface. They must descend and ascend slowly to avoid injury.

Extremely loud noises, such as explosions or gun blasts, can rupture the eardrum and fracture or dislocate the auditory ossicles. Loud noises may also damage the delicate tissues of the inner ear. Many cases of blast injuries of the middle ear can be surgically repaired, but those of the inner ear cannot.

Exposure to loud noises over a long period can also damage a person's hearing ability. People who work in noisy places or who often listen to loud music may suffer a gradual hearing loss. People should avoid loud noises as much as possible and wear ear protectors while in noisy places.

Certain drugs, including aspirin and some antibiotics, can damage the cochlear hair cells or the auditory nerve. A person who regularly takes such a drug may suffer from loss of hearing. In some cases, hearing is restored after the person stops taking the drug.

Diseases. The human ear is subject to a number of diseases. The most common ones include (1) otitis media, (2) otosclerosis, (3) acoustic neuroma, (4) Ménière's disease, and (5) presbycusis.

Otitis media is an infection of the middle ear. It most commonly strikes children and can cause severe hearing loss if not treated promptly. There are three main types of otitis media—*acute, chronic,* and *serous.*

Acute otitis media results when an infection of the nose or throat spreads to the middle ear. Pus accumulates in the middle ear, causing pain and some hearing loss. Most cases of acute otitis media can be treated with antibiotics.

Chronic otitis media is a middle ear infection that is especially severe or that occurs repeatedly. It may cause the eardrum to rupture. Pus then frequently oozes from the middle ear. In most cases, a ruptured eardrum heals naturally. In other cases, it must be surgically repaired. Surgeons repair a ruptured eardrum with connective tissue from a person's veins or muscles. In some cases of chronic otitis media, pus continuously drains from the ear. The infection gradually destroys the auditory ossicles. Skin from the external auditory canal may grow into the middle ear, forming a small sac called a *cyst.* If the skin cyst continues to grow, it may damage parts of the inner ear, the facial nerve, and the brain. Most skin cysts can be surgically removed, and the damaged auditory ossicles can be replaced with artificial or transplanted ones.

Serous otitis media results if the Eustachian tube, which connects the middle ear to the back of the throat, becomes blocked. The blockage may be due to a respiratory infection, adenoid infection, allergic reaction, or certain birth defects. The blockage causes fluid to build up in the middle ear. The fluid interferes with the transmission of sound vibrations across the eardrum and auditory ossicles. Ear pain and drainage, which are symptoms of acute and chronic otitis media, do not occur in serous otitis media. Physicians often treat serous otitis media by slitting the eardrum and inserting a tube to allow the fluid to drain. They then treat the condition that caused the Eustachian tube to become blocked.

Otosclerosis is a disease of the auditory ossicles. In most cases, it begins during early adulthood, and it may slowly progress. In otosclerosis, a spongy bonelike material grows around the stapes. As this material grows, it interferes with the movement of the stapes within the oval window. The person suffers a gradual hearing loss. Doctors do not know the causes of the disease. They treat it by replacing the stapes with an artificial one. In most cases, the surgery improves hearing ability.

Acoustic neuroma is a tumor of the auditory nerve. The victim suffers a gradual decline in hearing ability, *tinnitus* (ringing or other noises in the ears), and dizziness. The tumor can be surgically removed. If the tumor is not removed, it may grow into the base of the brain and seriously damage vital brain functions.

Ménière's disease is a disorder of the inner ear marked by periodic attacks of hearing loss, tinnitus, and vertigo. After repeated attacks, the victim may suffer severe hearing loss. The exact cause of the disease is not known. However, researchers have found that the condition involves an increase in the volume and pressure of the inner ear fluid. The pressure of the fluid damages the hair cells of the cochlea and the vestibular organs.

Physicians may prescribe certain drugs to relieve the vertigo caused by Ménière's disease. But the drugs cannot prevent hearing loss. In severe cases of the disease, surgery is performed to drain the excess fluid and so help reduce the pressure inside the inner ear. Doctors may also cut the vestibular nerve to prevent vertigo, but this surgery is performed only if the patient's hearing is poor.

Presbycusis is a gradual loss of hearing that occurs with aging. It commonly develops among people who are more than 60 years old. Some ear specialists believe that the disease occurs because the cochlear nerve, like other tissues of the body, simply wears out as a person grows older. Others believe that the number of hair cells in the inner ear decreases with age, resulting in hearing loss. Victims of presbycusis have difficulty especially in hearing high-pitched sounds. They also find it hard to hear in noisy environments. In addition, they may have tinnitus.

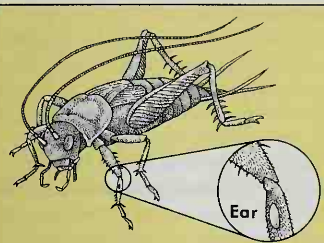
No cure has been found for presbycusis. Most people who have the disease can hear and understand speech fairly well. However, severely disabled people may benefit from hearing aids and lip-reading lessons. Family members can help relatives who have presbycusis by pronouncing words slowly and distinctly, and by using visual signs along with speech to communicate.

The ears of animals

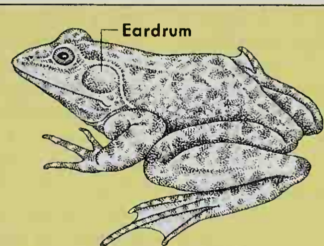
Many animals have ears that serve as organs of hearing and balance. But the structure of the ears varies greatly among different kinds of animals. Animals also differ in their ability to respond to sounds of exceptionally high or low frequency. For example, bats, cats,

Interesting features of the ears of various animals

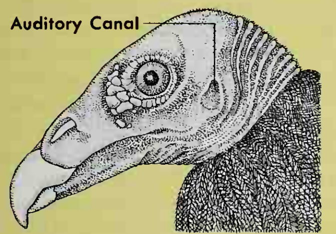
WORLD BOOK illustrations by Patricia J. Wynne



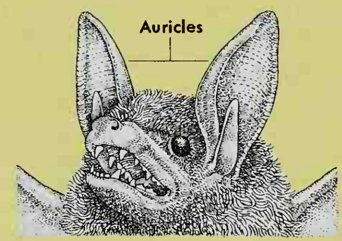
The "ears" of a cricket consist of a thin membrane on the side of each front leg. The membranes vibrate when sound waves strike them.



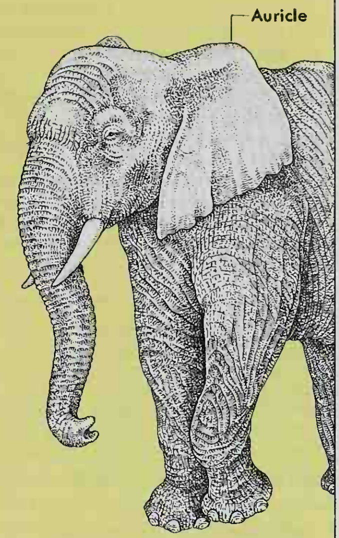
The eardrums of a frog consist of a large exposed disk behind each eye. Sound waves strike the eardrums, causing them to vibrate.



A vulture's auditory canals open along the sides of the head. Vultures, like all other animals except mammals, lack auricles.



The auricles of a bat are movable and so help channel sound waves into the ear. Bats depend on their hearing to navigate in the dark.



An African elephant's auricles are larger than those of any other mammal. They measure up to 4 feet (1.2 meters) wide.

dogs, some insects, and certain other animals can hear sounds of far higher frequency than human beings can hear.

Only a few kinds of insects have true hearing organs. Their "ears" consist simply of thin membranes that vibrate when sound waves strike them. Among different insects, the "ears" are on the legs, sides, or other parts of the body. See **Insect** (Hearing).

Fish do not have any outer ears or eardrums. But some fish have a simple type of inner ear on each side of the head. These fish can hear sound waves that travel through the water. Sound vibrations are carried to the inner ear by a gas-filled sac called the *air bladder.* Some types of fish have a chain of ossicles that connect the air bladder to the inner ear. See **Fish** (Hearing; Other senses).

Frogs, toads, and other amphibians have middle ears and inner ears. The middle ear of a frog consists of an eardrum and a small chamber with one bony ossicle. The eardrum of a frog is a large exposed disk behind the eye on each side of the head. See **Frog** (Senses).

Like amphibians, most reptiles have eardrums, middle ears, and inner ears. In some reptiles, the inner ears are highly developed. Most snakes lack eardrums, but they are not deaf, as many people think. Sounds are transmitted to the inner ears of snakes chiefly by the bones of the skull. See **Reptile** (Sense organs); **Snake** (Sense organs).

Birds have external auditory canals, middle ears, and inner ears. The cochlea of the inner ear is slightly curved but not coiled. The hearing ability of birds is similar to that of human beings. See **Bird** (Senses).

All mammals have coiled cochleas. In addition, mammals are the only animals that have auricles. In many mammals, these outer ear parts are movable and help channel sound waves into the auditory canal. African elephants have the largest auricles of any animal. Their auricles measure up to 4 feet (1.2 meters) wide. The auricles help the animals cool off in hot weather. Heat escapes from the elephant's body partly through the skin of the auricles. Other animals, including certain kinds of rabbits and foxes, have unusually large auricles that serve the same purpose. See **Mammal** (Senses).

A few animals, such as bats and whales, depend on their hearing to navigate in the dark. They find their way about by a process called *echolocation.* The animals make sounds and listen for the echoes that are produced when objects reflect the sounds. From the echoes, they determine the distance to an object and the direction in which it lies. See **Bat** (How bats navigate); **Whale** (Senses). David D. Caldarelli and Ruth S. Campanella

Related articles in *World Book* include:

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Outline

I. **Parts of the ear**
   A. The outer ear
   B. The middle ear
   C. The inner ear

II. **The sense of hearing**
   A. How sounds travel to the inner ear
   B. How sounds reach the brain

III. **The sense of balance**
   A. The response to movement
   B. The response to gravity
   C. Disturbances of the organs of balance

IV. Disorders of the ear
A. Birth defects
B. Injuries
C. Diseases
V. The ears of animals

Questions

What is *presbycusis?*
How do sounds reach the brain?
What is the *organ of Corti?*
What are the only animals that have auricles?
How do the semicircular canals work?
What are some kinds of injuries that can result in hearing loss?
What causes motion sickness?
How does earwax help protect the eardrum?
What causes the sensation of "popping" of the ears when you rapidly ascend or descend in an elevator or airplane?
How does *binaural hearing* enable a person to tell the direction from which a sound comes?

Additional resources

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Earhart, *AIR hahrt,* **Amelia** (1897-1937?), an American aviator, became the first woman to fly across the Atlantic Ocean alone. She was also the first woman to receive the Distinguished Flying Cross, which was awarded to her by the United States Congress.

Amelia Mary Earhart was born in Atchison, Kansas. A modest inheritance from her maternal grandmother gave her a secure life with opportunity for travel. She was a volunteer nurse during World War I (1914-1918).

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Amelia Earhart was an American pilot who became one of the world's most famous aviators. In 1937, Earhart disappeared without a trace while attempting to fly around the world. Since that time, her fate has been the source of much speculation.

In 1920, Earhart moved to California to live with her mother. While there, she became fascinated by aviation, which was a new and dangerous sport at that time. Earhart took flying lessons from Neta Snook, one of only a few women pilots in the 1920's. Earhart purchased her own plane and set an unofficial altitude record for women. In 1924, she moved to the East Coast. Earhart became a social worker in 1926, but she continued to fly.

In 1928, Earhart rode as an observer on a transatlantic airplane flight from Trepassey Bay, Newfoundland, to Burry Port, Wales. The flight made her the first woman to cross the Atlantic by air. In 1929, Earhart helped found the Ninety-Nines, an international organization of women pilots. In 1931, she married George Palmer Putnam, a wealthy publisher who had helped organize her 1928 flight. Earhart became the first woman to fly across the Atlantic Ocean alone in 1932. She took off from Harbour Grace, Newfoundland, and landed in a pasture near Londonderry, Northern Ireland. She went on to set other speed and distance records.

On May 20, 1937, Earhart and her navigator, Frederick J. Noonan, took off from Oakland, California, in an attempt to fly around the world. On June 1, after repairs and adjustments to their plane, they took off from Miami, Florida, and flew to Puerto Rico. On June 30, they landed in New Guinea. They had traveled about 20,000 miles (32,000 kilometers), more than three-fourths of their planned flight. On July 1, they left New Guinea and began the longest leg of the journey, a 2,600-mile (4,200-kilometer) flight to Howland Island in the central Pacific Ocean. The next day, a U.S. Navy vessel picked up radio messages from Earhart in which she reported empty fuel tanks. But efforts to make radio contact failed. A massive search found no trace of the plane or crew.

In later decades, some people claimed that the United States sent Earhart and Noonan to spy against Japanese forces in the Pacific. Many reports described captives resembling the two Americans on Japanese-held islands during World War II (1939-1945). But little convincing evidence supports these claims. It is more likely that Earhart's plane ran out of fuel after navigation errors took her off course. She and Noonan probably crashed into the ocean and died. Roger E. Bilstein

Additional resources

Butler, Susan. *East to the Dawn: The Life of Amelia Earhart.* Addison Wesley Longman, 1997.
Earhart, Amelia. *Last Flight.* 1937. Reprint. Crown, 1996.

Earle, Sylvia Alice (1935-), is an American oceanographer and environmentalist. In 1979, she was the first person to dive solo to 1,250 feet (381 meters) beneath the surface without being connected to a support vessel. During that dive, she reached the floor of the Pacific Ocean near Hawaii.

In 1981, Earle and her then-husband, engineer Graham Hawkes, founded a company called Deep Ocean Engineering. The company designs and builds underwater research vehicles known as *submersibles.* From 1990 to 1992, Earle served as chief scientist of the National Oceanic and Atmospheric Administration (NOAA), a branch of the Department of Commerce. For NOAA, Earle helped determine environmental damage

caused by Iraq's destruction of Kuwaiti oil wells during the Persian Gulf War in 1991.

Earle was born in Gibbstown, New Jersey. After graduating from Florida State University, she earned a Ph.D. degree in botany from Duke University. She is the author of more than 90 research papers and books, including *Sea Change: A Message from the Oceans* (1995).

Charles Pellegrino

See also **Exploration** (picture).

Early, Jubal Anderson (1816-1894), was a Confederate general in the American Civil War. He opposed *secession* (withdrawal) from the United States. But after Virginia seceded in 1861, he joined the Confederate Army and became a lieutenant general. He commanded a brigade and division in the Army of Northern Virginia.

Confederate General Robert E. Lee sent Early's corps in June 1864 to threaten Washington, D.C. Early bombarded the outskirts of the Union capital but was not able to take the city. Later in 1864, he participated in the burning of Chambersburg, Pennsylvania. He then retreated to the Shenandoah Valley and tried to delay the advance of the Union cavalry under General Philip H. Sheridan. Sheridan defeated Early in March 1865.

Early was born in Franklin County, Virginia, and graduated from the U.S. Military Academy in 1837. He then studied law. Early served in the Second Seminole War (1835-1842) and the Mexican War (1846-1848). After the Civil War, he helped found the Southern Historical Society, an organization that worked to preserve the Confederate view of the war. John F. Marszalek

Early childhood education provides planned learning experiences for children from birth through age 8. All early childhood education programs work to promote a child's emotional, intellectual, physical, and social development. Good programs strengthen children's feelings of self-worth and expand their ability to learn and organize information.

Young children learn from everyone and everything around them. But planned learning takes place chiefly in (1) activities planned by families, (2) formal education programs, and (3) child-care programs.

Activities planned by families give children a foundation for a lifetime of learning. Some activities occur at home as part of daily routines. For example, many families set aside a time each day to read to their youngest members. Other family activities may involve concerts, plays, or trips to museums or zoos.

Adults can obtain help in planning activities by attending parent education classes or participating in family support programs. These programs help families promote the development of their children and gain access to community resources or social services. Many print resources also provide suggestions for family learning.

Formal education programs include (1) programs for infants and toddlers; (2) preelementary programs, such as those offered by nursery schools and kindergartens; and (3) elementary programs. The best such programs are staffed by people with special training in educating young children. Early childhood educators believe that children's intellectual, social, emotional, and physical abilities are closely connected and should be developed at the same time. Skilled early childhood teachers create learning experiences appropriate for each child's stage of development and individual needs.

Child-care programs exist chiefly to provide care for the children of working families. Superior programs provide a safe environment, skilled adult supervision, and a wide range of activities, including educational experiences. Mary Renck Jalongo

Related articles in *World Book* include:

Child	Education (Early childhood education)	Head Start	Nursery school
Day care		Kindergarten	Parent education
		Montessori method	

Additional resources

Brewer, Jo Ann. *Introduction to Early Childhood Education.* 2nd ed. Allyn & Bacon, 1995.

Isenberg, Joan P., and Jalongo, Mary Renck, eds. *Major Trends and Issues in Early Childhood Education.* Teachers Coll. Pr., 1997.

Earnhardt, Dale (1951-2001), an American stock car driver, won the Winston Cup Championship seven times, tying the record set by Richard Petty. Earnhardt won the championship in 1980, 1986, 1987, 1990, 1991, 1993, and 1994. The Winston Cup series is the national racing championship for stock cars—American sedans with many modifications to increase speed and power. Earnhardt was noted for his aggressive driving style and his consistently high finishes in stock car races.

In 1979, he was named Winston Cup Rookie of the Year by the National Association for Stock Car Auto Racing (NASCAR). In 1980, Earnhardt became the only driver to win the Winston Cup Championship, which is governed by NASCAR, as a second-year competitor.

Ralph Dale Earnhardt was born in Kannapolis, North Carolina. Earnhardt began his racing career when he was 19 years old. He was the son of stock car pioneer Ralph Earnhardt. Dale Earnhardt was killed in a crash during the final lap of the Daytona 500 race in 2001. His son, Dale Earnhardt, Jr., is also a leading stock car driver.

Sylvia Wilkinson

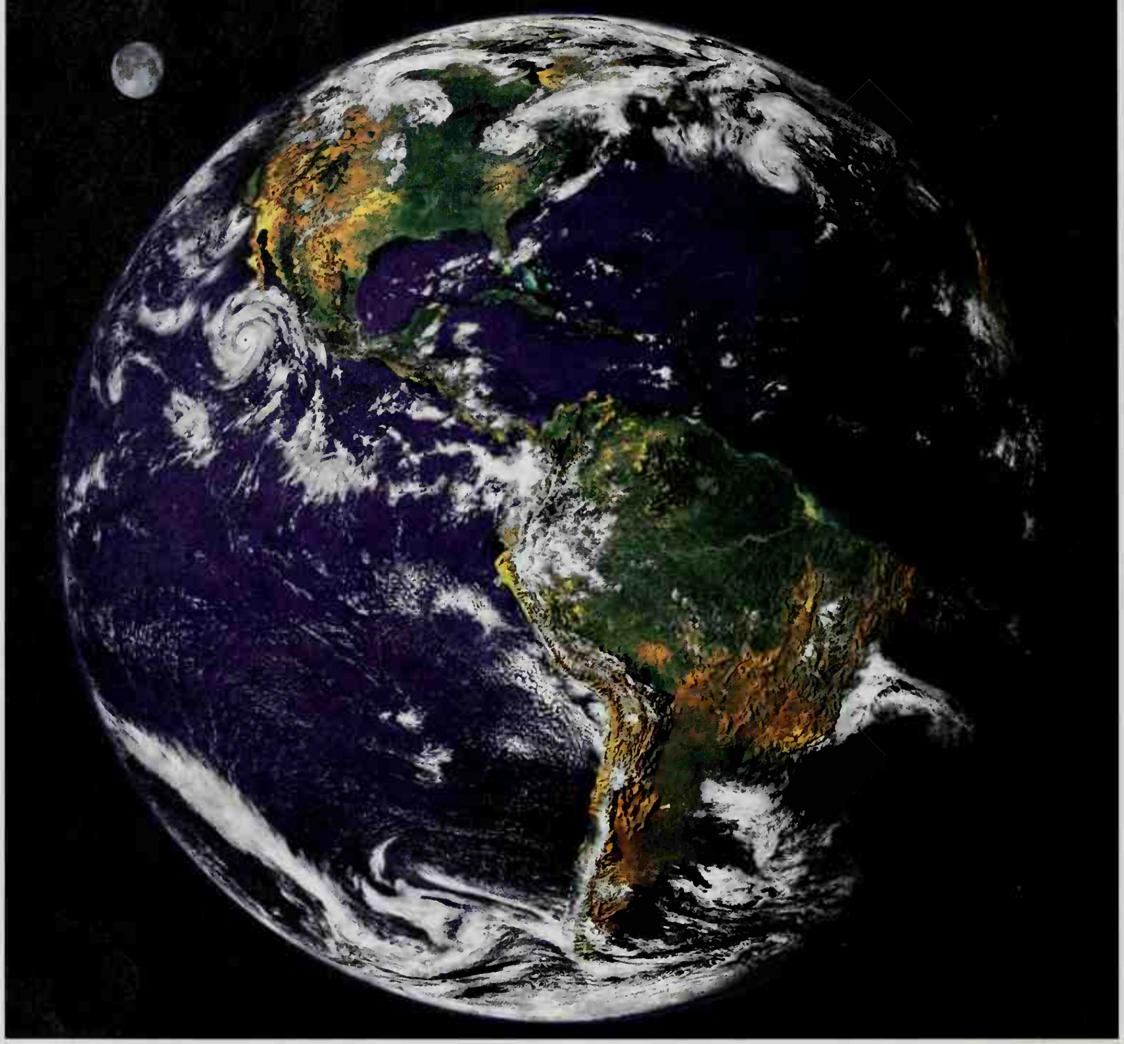
Earp, Wyatt (1848-1929), was a peace officer in the American West. He was best known for his role in the famous gunfight at the O.K. Corral in Tombstone, Arizona. Earp moved to Tombstone in 1879. He worked there as a stagecoach guard, card dealer, and deputy United States marshal. In 1881, a feud developed between Ike Clanton's gang and three of the Earp brothers—Wyatt, Virgil, and Morgan. Virgil was Tombstone's marshal. The feud peaked in October when the Earps and their friend Doc Holliday shot to death three of Clanton's gang at the O.K. Corral. The Earps said they were trying to make an arrest. Others said it was murder. Later, Wyatt worked as a saloonkeeper and prospector.


Montgomery Foto Service

Wyatt Earp

Wyatt Berry Stapp Earp was born in Monmouth, Illinois. As a young man, Earp worked as a buffalo hunter. During the 1870's, he was a police officer in Wichita and Dodge City in Kansas. Roger D. McGrath

Earphones. See **Headphones.**



NASA/Goddard Space Flight Center

Earth, our home planet, has oceans of liquid water and continents that rise above sea level. NASA scientists combined satellite photographs with surface data to create this detailed image of Earth's land masses and oceans. The swirling mass of clouds west of Mexico is a large hurricane.

Earth

Earth is a small planet in the vastness of space. It is one of nine planets that travel through space around the sun. The sun is a star—one of billions of stars that make up a galaxy called the Milky Way. The Milky Way and as many as 100 billion other galaxies make up the universe.

The planet Earth is only a tiny part of the universe, but it is the home of human beings and, in fact, all known life in the universe. Animals, plants, and other organisms live almost everywhere on Earth's surface. They can live on Earth because it is just the right distance from the sun. Most living things need the sun's warmth and light for life. If Earth were too close to the sun, it would be too hot for living things. If Earth were too far from the sun, it would be too cold for anything to live. Living things also must have water to live. Earth has plenty. Water covers most of Earth's surface.

Steven I. Dutch, the contributor of this article, is Professor of Earth Science at the University of Wisconsin, Green Bay.

The study of Earth is called *geology,* and scientists who study Earth are *geologists.* Geologists study different physical features of Earth to understand how they were formed and how they have changed over time. Much of Earth, such as the deep interior, cannot be studied directly. Geologists must often study samples of rock and use indirect methods to learn about the planet. Today, geologists can also view and study the entire Earth from space.

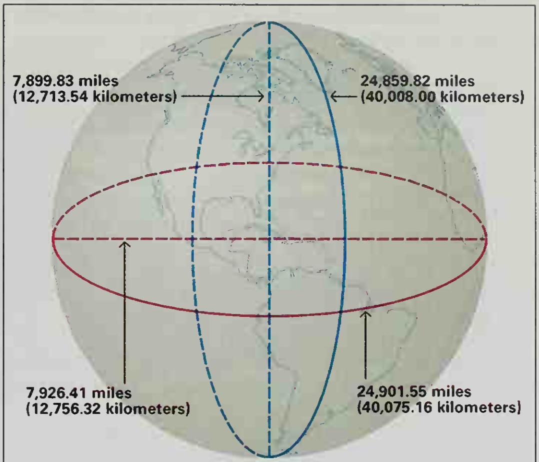
This article deals with the planet Earth as it is studied in geology. For information on the earth as the home of human beings, see the article on *World* in *World Book.*

Earth as a planet

Earth ranks fifth in size among the nine planets. It has a diameter of about 8,000 miles (13,000 kilometers). Jupiter, the largest planet, is about 11 times larger in diameter than Earth. Pluto, the smallest planet, has a diam-

Earth at a glance

Age: At least 4 $\frac{1}{2}$ billion years.
Mass: 6,600,000,000,000,000,000,000 (6.6 sextillion) tons (6.0 sextillion metric tons).
Motion: *Rotation* (spinning motion around an imaginary line connecting the North and South poles)—once every 23 hours 56 minutes 4.09 seconds. *Revolution* (motion around the sun)—once every 365 days 6 hours 9 minutes 9.54 seconds.
Size: *Polar diameter* (distance through Earth from the North Pole to the South Pole)—7,899.83 miles (12,713.54 kilometers). *Equatorial diameter* (distance through Earth at the equator)—7,926.41 miles (12,756.32 kilometers). *Polar circumference* (distance around Earth through the poles)—24,859.82 miles (40,008.00 kilometers). *Equatorial circumference* (distance around Earth along the equator)—24,901.55 miles (40,075.16 kilometers).
Area: *Total surface area*—196,900,000 square miles (510,000,000 square kilometers). *Land area*—approximately 57,100,000 square miles (148,000,000 square kilometers), 29 percent of total surface area. *Water area*—approximately 139,800,000 square miles (362,000,000 square kilometers), 71 percent of total surface area.
Surface features: *Highest land*—Mount Everest, 29,035 feet (8,850 meters) above sea level. *Lowest land*—shore of Dead Sea, about 1,310 feet (399 meters) below sea level.
Ocean depths: *Deepest part of ocean*—area of the Mariana Trench in Pacific Ocean southwest of Guam, 35,840 feet (10,924 meters) below surface. *Average ocean depth*—12,200 feet (3,730 meters).
Temperature: *Highest,* 136 °F (58 °C) at Al Aziziyah, Libya. *Lowest,* −128.6 °F (−89.6 °C) at Vostok Station in Antarctica. *Average surface temperature,* 59 °F (15 °C).
Atmosphere: *Height*—More than 99 percent of the atmosphere is less than 50 miles (80 kilometers) above Earth's surface. The atmosphere fades into space about 600 miles (1,000 kilometers) above the surface. *Chemical makeup of atmosphere*—about 78 percent nitrogen, 21 percent oxygen, 1 percent argon with small amounts of other gases.
Chemical makeup of Earth's crust (in percent of the crust's weight): oxygen 46.6, silicon 27.7, aluminum 8.1, iron 5.0, calcium 3.6, sodium 2.8, potassium 2.6, magnesium 2.0, and other elements totaling 1.6.



Earth is not perfectly round. Distances measured through the poles are shorter than those at the equator.

WORLD BOOK map

eter less than one-fifth that of Earth.

Earth, like all the planets in our solar system, travels around the sun in a path called an *orbit.* Earth is about 93 million miles (150 million kilometers) from the sun. It takes one year for Earth to complete one orbit around the sun. The innermost planet, Mercury, is only about one-third as far from the sun as Earth and circles the sun in only 88 days. Pluto, the outermost planet, is 40 times as far from the sun as Earth and takes 248 Earth years to circle the sun.

How Earth moves. Earth has three motions: (1) It spins like a top around an imaginary line called an *axis* that runs from the North Pole to the South Pole, (2) it travels around the sun, and (3) it moves through the Milky Way along with the sun and the rest of the solar system.

Earth takes 24 hours to spin completely around on its axis so that the sun is in the same place in the sky. This period is called a *solar day.* During a solar day, Earth moves a little around its orbit so that it faces the stars a bit differently each night. Thus, it takes only 23 hours 56 minutes 4.09 seconds for Earth to spin once so that the stars appear to be in the same place in the sky. This period is called a *sidereal day.* A sidereal day is shorter than a solar day, so the stars appear to rise about 4 minutes earlier each day.

Earth takes 365 days 6 hours 9 minutes 9.54 seconds to circle the sun. This length of time is called a *sidereal year.* Because Earth does not spin a whole number of times as it goes around the sun, the calendar gets out of step with the seasons by about 6 hours each year. Every four years, a day is added to bring the calendar back into line with the seasons. These years, called *leap years,* have 366 days. The extra day is added to the end of February and occurs as February 29.

The distance around Earth's orbit is 584 million miles (940 million kilometers). Earth travels in its orbit at 66,700 miles (107,000 kilometers) an hour, or 18.5 miles (30 kilometers) a second. Earth's orbit lies on an imaginary flat surface around the sun called the *orbital plane.*

Earth's axis is not straight up and down, but is tilted by about 23 $\frac{1}{2}$ degrees compared to the orbital plane. This tilt and Earth's motion around the sun causes the change of the seasons. In January, the northern half of Earth tilts away from the sun. Sunlight is spread thinly over the northern half of Earth, and the north experiences winter. At the same time, the sunlight falls intensely on the southern half of Earth, which has summer. By July, Earth has moved to the opposite side of the sun. Now the northern half of Earth tilts toward the sun. Sunlight falls intensely over the northern half of Earth, and the north experiences summer. At the same time, the sunlight falls less intensely on the southern half of Earth, which has winter.

Earth's orbit is not a perfect circle. Earth is slightly closer to the sun in early January (winter in the Northern Hemisphere) and farther away in July. In January, Earth is 91.4 million miles (147.1 million kilometers) from the sun, and in July it is 94.5 million miles (152.1 million kilometers) from the sun. This variation has a far smaller effect than the heating and cooling caused by the tilt of Earth's axis.

Earth and the solar system are part of a vast disk of stars called the Milky Way Galaxy. Just as the moon or-

bits Earth and planets orbit the sun, the sun and other stars orbit the tightly packed center of the Milky Way. The solar system is about two-fifths of the way from the center of the Milky Way and revolves around the center at about 155 miles (249 kilometers) per second. The solar system makes one complete revolution around the center of the galaxy in about 220 million years.

Earth's size and shape. Most people picture Earth as a ball with the North Pole at the top and the South Pole at the bottom. Earth, other planets, large moons, and stars—in fact, most objects in space bigger than about 200 miles (320 kilometers) in diameter—are round because of their gravity. Gravity pulls matter in toward the center of objects. Tiny moons, such as the two moons of Mars, have so little gravity that they do not become round, but remain lumpy instead.

To our bodies, "down" is always the direction gravity is pulling. People everywhere on Earth feel "down" is toward the center of Earth and "up" is toward the sky. People in Spain and in New Zealand are on exactly opposite sides of Earth from each other, but both sense their surroundings as "right side up." Gravity works the same way on other planets and moons.

Earth, however, is not perfectly round. Earth's spin causes it to bulge slightly at its middle, the *equator.* The diameter of Earth from North Pole to South Pole is 7,899.83 miles (12,713.54 kilometers), but through the equator it is 7,926.41 miles (12,756.32 kilometers). This difference, 26.58 miles (42.78 kilometers), is only $\frac{1}{298}$ the diameter of Earth. The difference is too tiny to be easily seen in pictures of Earth from space, so the planet appears round.

Earth's bulge also makes the circumference of Earth larger around the equator than around the poles. The circumference around the equator is 24,901.55 miles (40,075.16 kilometers), but around the poles it is only 24,859.82 miles (40,008.00 kilometers). The circumference is actually greatest just south of the equator, so Earth is slightly pear-shaped. Earth also has mountains and valleys, but these features are tiny compared to the total size of Earth, so the planet appears smooth from space.

Earth and its moon. Earth has one moon. Pluto also has one moon, while Mercury and Venus have none. All the other planets in our solar system have two or more moons. Earth's moon has a diameter of about 2,160 miles (3,476 kilometers)—about one-fourth of Earth's diameter.

The sun's gravity acts on Earth and the moon as if they were a single body with its center about 1,000 miles (1,600 kilometers) below Earth's surface. This spot is the Earth-moon *barycenter.* It is the point of balance between the heavy Earth and the lighter moon. The path of the barycenter around the sun is a smooth curve. Earth and the moon circle the barycenter as they orbit the sun. The motion of Earth and moon around the barycenter makes each "wobble" in their path around the sun.

Earth's spheres

Earth is composed of several layers, or *spheres,* somewhat like the layers of an onion. The solid Earth consists of a thin outer layer, the *crust,* with a thick rocky layer, the *mantle,* beneath it. The crust and the upper portion of the mantle are called the *lithosphere.* At the center of Earth is the *core.* The outer part of the core is liquid, while the inner part is solid. Much of Earth is covered by a layer of water or ice called the *hydrosphere.* Earth is surrounded by a thin layer of air, the *atmosphere.* The portion of the hydrosphere, atmosphere, and solid land where life exists is called the *biosphere.*

The atmosphere. Air surrounds Earth and becomes progressively thinner farther from the surface. Most people find it difficult to breathe more than 2 miles (3 kilometers) above sea level. About 100 miles (160 kilometers) above the surface, the air is so thin that satellites can travel without much resistance. Detectable traces of atmosphere, however, can be found as high as 370 miles (600 kilometers) above Earth's surface. The atmosphere has no definite outer edge but fades gradually into space.

Nitrogen makes up 78 percent of the atmosphere, while oxygen makes up 21 percent. The remaining 1 percent consists of argon and small amounts of other gases. The atmosphere also contains water vapor, carbon dioxide, water droplets, dust particles, and small amounts of many other chemicals released by volcanoes, fires, living things, and human activities.

The lowest layer of the atmosphere is called the *troposphere.* This layer is in constant motion. The sun heats

The motions of Earth

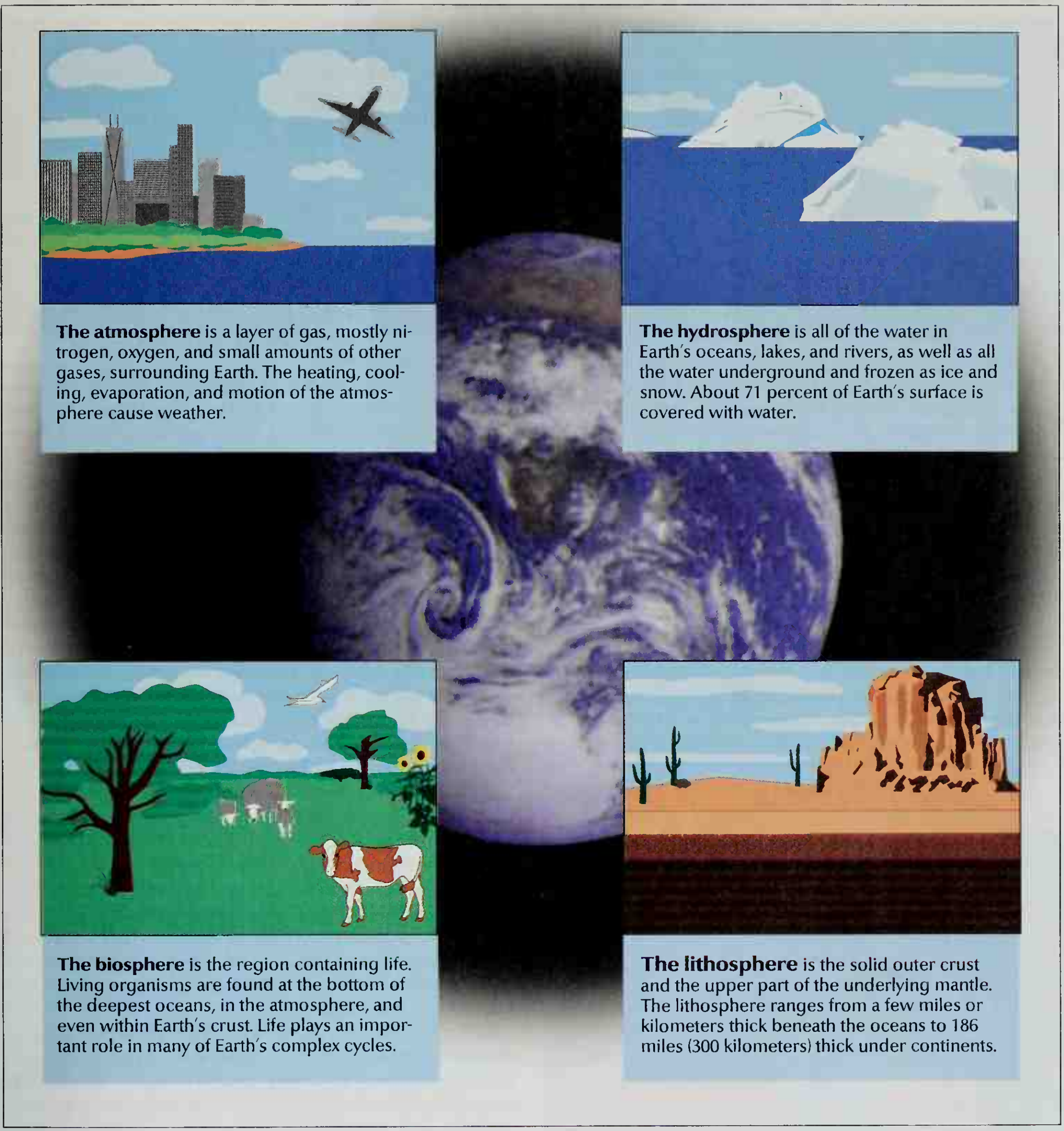
Earth spins around its axis once every 24 hours. This motion creates day and night. Earth also travels around the sun once every 365 days. This motion creates the year. The entire solar system revolves around the center of the Milky Way Galaxy.

WORLD BOOK illustration by Amie Zorn, Artisan-Chicago

Earth's spheres

Earth's layers, or *spheres*—the atmosphere, hydrosphere, lithosphere, and biosphere—form a complex system that interacts and functions as a whole. Matter and energy flow constantly back and forth between the spheres in cycles. A change in one can produce unexpected changes in another.

NASA; WORLD BOOK illustrations by Amie Zorn, Artisan-Chicago



The atmosphere is a layer of gas, mostly nitrogen, oxygen, and small amounts of other gases, surrounding Earth. The heating, cooling, evaporation, and motion of the atmosphere cause weather.

The hydrosphere is all of the water in Earth's oceans, lakes, and rivers, as well as all the water underground and frozen as ice and snow. About 71 percent of Earth's surface is covered with water.

The biosphere is the region containing life. Living organisms are found at the bottom of the deepest oceans, in the atmosphere, and even within Earth's crust. Life plays an important role in many of Earth's complex cycles.

The lithosphere is the solid outer crust and the upper part of the underlying mantle. The lithosphere ranges from a few miles or kilometers thick beneath the oceans to 186 miles (300 kilometers) thick under continents.

Earth's surface and the air above it, causing warm air to rise. As the warm air rises, air pressure decreases and the air expands and cools. The cool air is denser than the surrounding air, so it sinks and the cycle starts again. This constant cycle of the air causes the weather.

High above the troposphere, about 30 miles (48 kilometers) above Earth's surface, is a layer of still air called the *stratosphere*. The stratosphere contains a layer where ultraviolet light from the sun strikes oxygen molecules to create a gas called *ozone*. Ozone blocks most of the harmful ultraviolet rays from reaching Earth's surface. Some ultraviolet rays get through, however. They are responsible for sunburn and can cause skin cancer in people. Tiny amounts of human-made chemicals have caused some of the natural ozone to break down. Many people are concerned that the ozone layer may become too thin, allowing ultraviolet rays to reach the surface and harm people and other living things.

Water vapor, carbon dioxide, methane, and other gases in the atmosphere trap heat from the sun, warming Earth. The heat-trapping quality of these gases causes the *greenhouse effect*. Without the greenhouse effect of the atmosphere, Earth would probably be too cold for life to exist.

The hydrosphere. Earth is the only planet in the solar system with abundant liquid water on its surface. Water has chemical and physical properties not matched by any other substance, and it is essential for life on Earth. Water has a great ability to absorb heat. The oceans store much of the heat Earth gets from the sun. The electrical charges on water molecules give water a great ability to attract atoms from other substances. This quality allows water to dissolve many things. Water's ability to dissolve materials makes it a powerful agent in breaking down rocks. Liquid water on Earth affects not just the surface but the interior as well. Water in rocks lowers the melting temperature of rock. Water dramatically weakens rocks and makes them easier to melt beneath Earth's surface.

About 71 percent of Earth's surface is covered by water, most of it in the oceans. Ocean water is too salty to drink. Only about 3 percent of Earth's water is fresh water, suitable for drinking. Much of Earth's fresh water is not readily available to people because it is frozen in the polar icecaps or beneath Earth's surface. Polar regions and high mountains stay cold enough for water to remain permanently frozen. The region of permanent ice on Earth is sometimes called the *cryosphere.*

The lithosphere. The crust and upper mantle of Earth from the surface to about 60 miles (100 kilometers) down make up the lithosphere. The thin crust is made up of natural chemicals called *minerals* composed of different combinations of elements. Oxygen is the most abundant chemical element in rocks in Earth's crust, making up about 47 percent of the mass of all rock. The second most abundant element is silicon, 27 percent, followed by aluminum (8 percent), iron (5 percent), calcium (4 percent), and sodium, potassium, and magnesium (about 2 percent each). These eight elements make up 99 percent of the mass of rocks on Earth's surface.

Two elements, silicon and oxygen, make up almost three-fourths of the crust. This combination of elements is so important that geologists have a special term for it: *silica.* Minerals that contain silica are called *silicate minerals.* The most abundant mineral on Earth's surface is quartz, made up of pure silica. Another plentiful group of silicates are the *feldspars,* which consist of silica, aluminum, calcium, sodium, and potassium. Other common silicate minerals on Earth's surface are pyroxene (pronounced *PY rahk seen)* and amphibole (pronounced *AM fuh bohl),* which consist of combinations of silica, iron, and magnesium.

Another important group of minerals are the *carbonates,* which contain carbon and oxygen along with small amounts of other elements. The most important carbonate mineral is *calcite,* made up of calcium, carbon, and oxygen. *Limestone,* a common rock used for building, is mostly calcite. Another important carbonate is *dolomite,* composed of carbon, oxygen, calcium, and magnesium.

Earth has two kinds of crust. The dry land of the continents is made up mostly of granite and other light silicate minerals, while the ocean floors are composed mostly of a dark, dense volcanic rock called *basalt.* Continental crust averages about 25 miles (40 kilometers) thick, but it is thicker in some areas and thinner in others. Most oceanic crust is only about 3 miles (5 kilometers) thick. Water fills in the low areas over the thin basalt crust to form the world's oceans. There is more than enough water on Earth to completely fill the oceanic basins, and some of it spreads onto the edges of the continents. This portion of the continents surrounded by a band of shallow ocean is called the *continental shelf.*

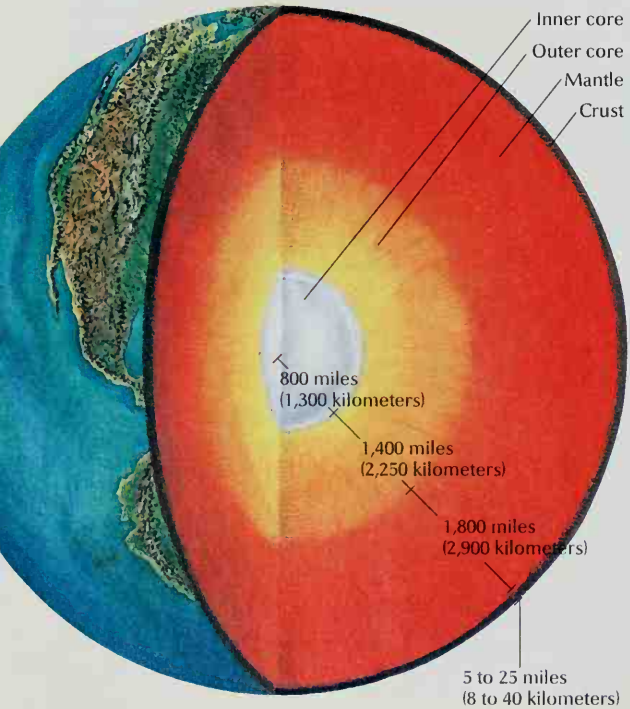
The biosphere. Earth is the only planet in the universe known to have life. The region containing life extends from the bottom of the deepest ocean to a few miles or kilometers into the atmosphere. There are several million known kinds, called *species,* of living things, and scientists believe that there are far many more species not yet discovered.

Life affects Earth in many ways. Life has actually made the atmosphere around us. Plants take in water and carbon dioxide, both of which contain oxygen. They use the carbon in carbon dioxide and the hydrogen in water to make chemicals of many kinds and give off oxygen as a waste product. Animals eat plants to get energy and return water and carbon dioxide back into the environment. Living things affect the surface of Earth in other ways as well. Plants create chemicals that speed the breakdown of rock. Grasslands and forests slow the erosion of soil.

Inside Earth

Beneath Earth's solid crust are the mantle, the outer core, and the inner core. Scientists learn about the inside of Earth by studying how waves from earthquakes travel through the planet.

WORLD BOOK illustration by Raymond Perlman and Steven Brayfield, Artisan-Chicago

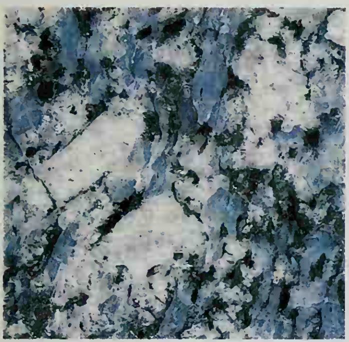


Earth's rocks

The solid part of Earth consists of rocks, which are sometimes made up of a single mineral, but more often consist of mixtures of minerals. Geologists classify rocks according to their origin. *Igneous rocks* form when molten rock cools and solidifies. *Sedimentary rocks*

Earth's three kinds of rocks

Geologists classify rocks into three main kinds, according to their origin: (1) igneous, (2) sedimentary, and (3) metamorphic. Each type of rock is formed through a different process.



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Granite, an igneous rock, is formed mainly by the slow cooling of molten rock from deep inside the crust.

© Joe McDonald, Bruce Coleman Inc.

Limestone, a sedimentary rock, forms when the mineral calcite from the shells of marine organisms solidifies into rock.

© Lee Boltin

Gneiss and other metamorphic rocks result when igneous and sedimentary rocks are changed by heat and pressure.

form when grains of rock or dissolved chemicals are deposited in layers by wind, water, or glaciers. Over time, the layers harden into solid rock. *Metamorphic rocks* develop deep in Earth's crust when heat or pressure transform other types of rock.

Igneous rocks form from molten material called *magma.* Most of Earth's interior is solid, not molten, but it is extremely hot. At the base of Earth's crust, the temperature is about 1800 °F (1000 °C). In some portions of the crust, conditions are right for rocks to melt. Rocks can melt more easily near the crust if they contain water, which lowers their melting point.

Where conditions are right, small pockets of magma form beneath and within the crust. Some of this magma reaches the surface, where it erupts from volcanoes as lava. Igneous rocks formed this way are called *volcanic* or *extrusive.* Vast quantities of magma, however, never reach the surface. They cool slowly within the crust and may only be exposed long afterward by erosion. Such igneous rocks are called *plutonic* or *intrusive.* Plutonic rocks cool slowly. During this slow cooling, their minerals form large crystals. Plutonic rocks tend to be much coarser than volcanic rocks.

Igneous rocks that are rich in silica tend to be poor in iron and magnesium, and the opposite is also true. Volcanic rocks that are iron-rich and silica-poor are basalt. Plutonic rocks of the same makeup are called *gabbro.* Silica-rich volcanic rocks are called *rhyolite (RY uh lyt),* and plutonic rocks of the same composition are granite. Granite lies under most of the continents, while basalt lies under most of the ocean floors.

Sedimentary rocks. Rocks on Earth's surface are under constant attack by chemicals and mechanical forces. The processes that break down rocks are called *weathering.* Water is effective at dissolving minerals. When water freezes, it expands, so expanding ice helps pry apart mineral grains in rocks. In addition, living things produce chemicals that help dissolve rocks.

Once rocks break apart, the loose material is often carried away by erosion. Running water erodes rocks. Wind and glaciers also contribute to erosion. Erosion is usually a relatively slow process, but over millions of years, erosion can uncover even rocks many miles or kilometers below the surface.

Materials derived from weathering and erosion of rocks are eventually deposited to form sedimentary rocks. Rocks that are made up of small pieces of other rocks are called *clastic rocks.* Rocks containing larger pebbles are called *conglomerate.* The particles in these rocks are cemented together when minerals dissolved in the water crystallize between the grains. The most abundant sedimentary rocks, called *mudrocks,* consist of tiny particles. Some of these rocks, called *shale,* split into thin sheets when broken. Sandstone is a sedimentary rock made up of sand cemented together.

Other sedimentary rocks form when dissolved materials undergo chemical reactions and settle out as tiny solid particles. These rocks are called *chemical sedimentary rocks.* Common chemical sedimentary rocks include some types of limestone and dolomite. Some chemical sedimentary rocks form when water evaporates, leaving dissolved materials behind. Rock salt and a mineral called *gypsum* form this way.

Some sedimentary rocks, called *biogenic,* are formed by the action of living things. Coal is the remains of woody plants that have been transformed into rock by heat and pressure over time. Most limestone is formed by microscopic marine organisms that secrete protective shells of calcium carbonate. When the animals die, the shells remain and solidify into limestone.

Metamorphic rocks. When rocks are buried deeply, they become hot. Earth's crust grows hotter by about 70 °F per mile (25 °C per kilometer) of depth. Pressure also increases with depth. At a depth of 1 mile (1.6 kilometers) beneath the surface, the pressure is about 6,000 pounds per square inch (41,360 kilopascals). As rocks are heated and subjected to pressure, minerals react and the rocks become metamorphic. Shale is transformed to slate, limestone, and eventually into marble under pressure. Many metamorphic rocks contain recognizable features that tell of their origin, but others change so much that only the chemical makeup pro-

vides evidence of what they originally were.

Cycles on and in Earth

Earth can be thought of as a huge system of interacting cycles. In each cycle, matter and energy move from place to place and may change form. Eventually, matter and energy return to their original condition and the cycle begins again. The cycles affect everything on the planet, from the weather to the shape of the landscape. There are many cycles on and within Earth. A few of the most important are (1) atmospheric circulation, (2) ocean currents, (3) the global heat conveyor, (4) the hydrologic cycle, and (5) the rock cycle.

Atmospheric circulation. Air warmed by the sun near the equator rises and flows toward Earth's poles, returning to the surface and flowing back to the equator. This motion, combined with the rotation of Earth, moves heat and moisture around the planet creating winds and weather patterns.

In some areas, the winds change directions with the seasons. These patterns are often called *monsoons.* In summer, air over Asia is heated by the sun, rises, and draws moist air from the Indian Ocean, causing daily rains over most of southern Asia. In winter, the air over Asia cools, sinks, and flows out, pushing the moist air away and creating dry weather. A similar pattern occurs in the Pacific Ocean near Mexico and brings moist air and afternoon thunderstorms to the southwestern United States in the summer.

Ocean currents are driven by the winds and follow the same general pattern. The continents block the flow of water around the globe, so ocean currents flow west near the equator, then turn toward the poles when they strike a continent, turn east, then flow back to the equator on the other side. In all the oceans, the ocean currents form great loops called *gyres.* The gyres flow clockwise north of the equator and counterclockwise south of it.

The global heat conveyor is an enormous cycle of ocean water that distributes the oceans' heat around Earth. Water in the polar regions is very cold, salty, and dense. It sinks and flows along the sea floor toward the equator. Eventually, the water rises along the margins of the continents and merges with the surface water flow. When it reaches the polar regions, it sinks again. This three-dimensional movement of water mixes heat throughout the oceans, warming polar waters. It also brings nutrients up from the deep ocean to the surface, where they are available for marine plants and animals.

The hydrologic cycle. Water from the oceans evaporates and is carried by the atmosphere, eventually falling as rain or snow. Water that falls on the land helps break rocks down chemically, nourishes plants, and wears down the landscape. Eventually, the water returns to the sea to start the cycle over again.

The rock cycle. Earth has many more kinds of rocks compared to other planets because there are so many processes acting to form and break down rocks. Geologists sometimes speak of the *rock cycle* to explain how different rock types are related. The cycle may begin with a flow of lava from a volcano cooling to form new igneous rocks on Earth's surface. As the rock is exposed to water, it breaks down and the resulting materials may be carried away to be deposited as sedimentary rocks. These rocks may eventually be so deeply buried that they change in form to become metamorphic rocks. They may even melt, creating the raw material for the next generation of igneous rocks.

Rocks rarely go through the entire rock cycle. Instead, some steps may be skipped or repeated. For example, igneous rocks can be subjected to heat and pressure and transformed directly to metamorphic rocks. Sedimentary rocks can be broken down by weathering and then reassembled into a new generation of sedimentary rocks. Metamorphic rocks can also be weathered to form the raw material for a new generation of sedimentary rocks. Any rock type, igneous, metamorphic, or sedimentary, can be transformed into any other type.

© David Muench

Lichens help to form soil. These rootless, plantlike organisms produce an acid that dissolves parts of rocks. Bits of rock then mix with decaying matter to form soil.

© Derek Croucher, Corbis Stock Market

Flowing water erodes rocks, dissolving minerals and depositing them elsewhere. Over millions of years, water can carve deep channels into solid rock, such as this sandstone in Arizona.

Earth's interior

Geologists cannot study the interior of Earth directly. The deepest wells drilled reach less than 8 miles (13 kilometers) below the surface. Geologists know that the whole Earth differs in composition from its thin outer crust. Deep in Earth, pressures are so great that minerals can be compressed into dense forms not found on the surface.

One way geologists determine the overall composition of Earth is from chemical analysis of meteorites. Certain types of meteorites, called *chondrites,* are remains of the early solar system that persisted unchanged in space until they fell to Earth. Geologists can use chondrites to estimate the original chemical composition of the entire Earth.

Unlike chondrites, Earth is made up of layers that contain different amounts of various chemical elements. Geologists learn about Earth's interior by studying vibrations generated by earthquakes, using instruments called *seismographs.* The speed and motion of vibrations traveling through Earth depends on the composition and density of the material they travel through. Geologists can determine many properties of Earth's interior by analyzing such vibrations.

The mantle. Beneath the crust, extending down about 1,800 miles (2,900 kilometers), is a thick layer called the mantle. The mantle is not perfectly stiff but can flow slowly. Earth's crust floats on the mantle much as a board floats in water. Just as a thick board would rise above the water higher than a thin one, the thick continental crust rises higher than the thin oceanic crust. The slow motion of rock in the mantle moves the continents around and causes earthquakes, volcanoes, and the formation of mountain ranges.

The core. At the center of Earth is the core. The core is made mostly of iron and nickel and possibly smaller amounts of lighter elements, including sulfur and oxygen. The core is about 4,400 miles (7,100 kilometers) in diameter, slightly larger than half the diameter of Earth and about the size of Mars. The outermost 1,400 miles (2,250 kilometers) of the core are liquid. Currents flowing in the core are thought to generate Earth's magnetic field. Geologists believe the innermost part of the core, about 1,600 miles (2,600 kilometers) in diameter, is made of a similar material as the outer core, but it is solid. The inner core is about four-fifths as big as Earth's moon.

Earth gets hotter toward the center. At the bottom of the continental crust, the temperature is about 1800 °F (1000 °C). The temperature increases about 3 °F per mile (1 °C per kilometer) below the crust. Geologists believe the temperature at the center of Earth is about 5500 to 9000 °F (3000 to 5000 °C). The center of Earth is almost as hot as the surface of the sun. But, because it is under great pressures, the rock in the center of Earth remains solid.

Earth's crust

The hot rock deep in Earth's mantle flows upward slowly, while cooler rock near the surface sinks because hot materials are lighter than cool materials. The rising and sinking of materials due to differences in temperature is called *convection.* As Earth's mantle flows, it breaks the crust into a number of large slabs called *tectonic plates,* much as slabs of ice break apart on a pond. The slow flow of Earth's mantle drags the crust along, causing the continents to move, mountains to form, and volcanoes and earthquakes to occur. This constant motion of Earth's crust is called *plate tectonics.*

In some places, usually under the oceans, Earth's plates are spreading apart. New magma from the mantle rises to fill the cracks between the plates. Places where plates spread apart are called *spreading centers.* Many

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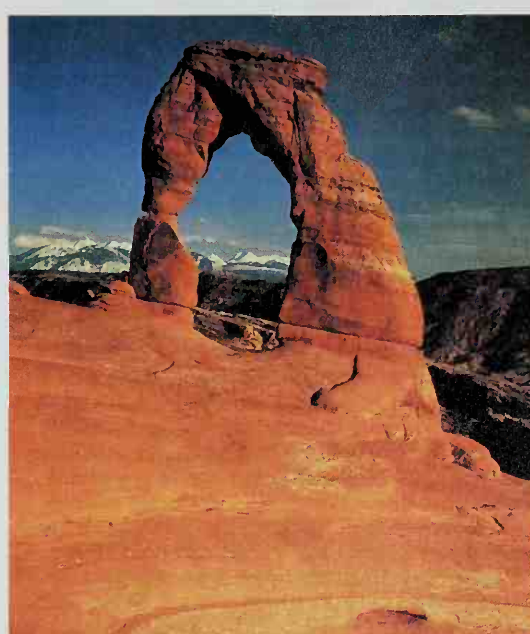
Glaciers scour valleys and flatten landscapes. The heavy mass of ice grinds away rock, which it carries away in dark ribbons and leaves behind as a ridge called a *moraine* when it melts.



© David Muench

Wind erosion sculpted Delicate Arch in Utah from a wall of ancient sandstone. Wind-driven sand wore away soft parts of the rock to reveal the unusual shape.

volcanoes occur where plates pull apart and magma wells up from within the mantle to fill the gap. The material from the mantle is made of iron and magnesium-rich silicate rocks. It hardens to form rocks and creates oceanic crust made of basalt.

Subduction. Earth's crust cannot spread apart everywhere. Somewhere, an equal amount of crust must be removed. When two plates push together, one of the plates sinks back into Earth's mantle, a process called *subduction.* The sinking plate eventually melts into magma in Earth's interior. Much of the magma created in subduction zones does not reach the surface and cools within the crust, forming plutonic rocks. The heat from the magma also helps create metamorphic rocks.

Continental crust is too thick and light to sink into Earth's interior, so only plates of dense oceanic crust are subducted. The boundary where the two plates meet is marked by a deep trench on the ocean floor. The trenches are the deepest places in the oceans, up to 36,000 feet (11,000 meters) deep.

The upper plate that remains on the surface when two plates collide may be continental crust or oceanic crust. This plate is also changed by subduction. As the two plates move together, the edge of the upper plate is compressed. The crust becomes thicker and higher, creating a mountain range. When the rocks of the sinking plate reach a depth of about 60 miles (100 kilometers), they begin to melt and form magma. Some of the magma reaches the surface to form volcanoes. Regions with many volcanoes, such as Peru, Japan, and the northwestern United States, lie near areas where subduction is happening.

Mountain building. Occasionally, as a plate sinks into Earth's mantle, it drags along a continent or a smaller land mass. Continental crust is too thick and light to sink. Instead, it collides with the opposing plate. If the opposing plate is also a continent, neither plate will sink. This type of collision often forms a vast mountain chain in the middle of a continent. The Himalaya were formed in such a way from the collision of two plates of continental crust.

The series of events that happen during formation of a mountain range is called *orogeny.* Orogeny includes the elevation of mountains, folding and crumpling of the rocks, volcanic activity, and formation of plutonic and metamorphic rocks that occur when plates collide. Long after mountains have vanished from erosion, geologists can still see the changes orogeny produces in the rocks.

Terrane collisions. Smaller pieces of continental crust that collide with another plate are often added to the edge of the larger plate. These small added pieces of crust are called *terranes.* Most of the land in the United States west of Salt Lake City has been added to North America by terrane collisions in the last 500 million years.

Earthquakes. Earthquakes occur when rocks on opposite sides of a break in the crust, called a *fault,* slide past each other. The boundaries between plates are faults, but there are faults within plates as well. Occasionally, forces within the plates cause rocks to fracture and slip even though the rocks are not at a plate boundary. The boundaries between two plates sliding past each other are called *transform faults.* The San Andreas Fault in California is a transform fault, where a portion of crust called the Pacific Plate is carrying a small piece of California northwest past the rest of North America.

The shaping of the continents. Several times in Earth's history, collisions between continents have created a huge *supercontinent.* Although the crust of the continents is thick, it breaks more easily than oceanic crust, and supercontinents broke quickly into smaller pieces. Material from Earth's mantle filled the gaps, creating new oceanic crust. As the continents moved apart, new ocean basins formed between them. About one-third of Earth's surface is covered by continental crust, so the pieces cannot move far before colliding. As two continents collide, an old ocean basin is destroyed. The process of continents breaking apart and rejoining is called the *Wilson cycle,* after the Canadian geologist John Tuzo Wilson, who first described it.

The continents have probably been in motion for at least the past 2 billion years or more. Geologists, however, only have evidence from rocks to understand and reconstruct the motion over the past 800 million years. Most of the oceanic crust older than that has been subducted into the mantle long ago.

Geologists have determined that, about 800 million years ago, the continents were assembled into a large supercontinent called Rodinia. What is now North America lay at the center of Rodinia. The flow of material in Earth's mantle caused Rodinia to break apart into many pieces, which collided again between 500 million and 250 million years ago. Collision between what is now North America, Europe, and Africa caused the uplift of the Appalachian Mountains in North America. Collisions between part of present-day Siberia and Europe created the Ural Mountains.

By 250 million years ago, the continents reassembled to form another supercontinent called Pangaea. A single, worldwide ocean, called Panthalassa, surrounded Pangaea. About 200 million years ago, Pangaea began to break apart. It split into two large land masses called Gondwanaland and Laurasia. Gondwanaland then broke apart, forming the continents of Africa, Antarctica, Australia, and South America, and the Indian subcontinent. Laurasia eventually split apart into Eurasia and North America. As the continental plates split and drifted apart, new oceanic crust formed between them. The movement of the continents to their present positions took place over millions of years.

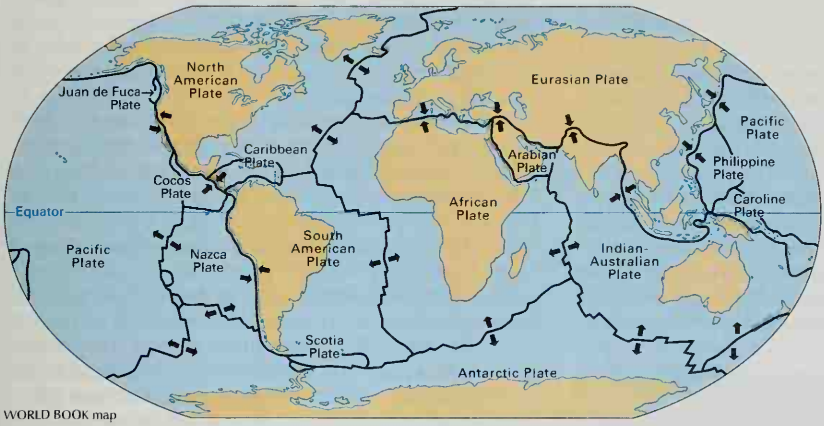
Earth's changing climate

The ice ages. Throughout the history of Earth, the climate has changed many times. Between 800 million and 600 million years ago, during a time called the Precambrian, Earth experienced several extreme climate changes called *ice ages* or *glacial epochs.* The climate grew so cold that some scientists believe Earth nearly or completely froze several times. The theory that the entire Earth froze is sometimes called the *snowball Earth.* Geologists estimate that Earth experienced up to four such periods of alternate freezing and thawing.

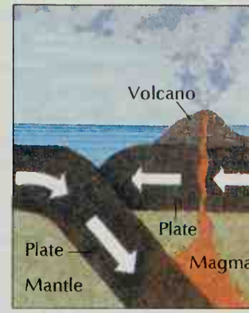
Most of the time, Earth has been largely ice free. Brief ice ages occurred about 450 million years ago and again about 250 million years ago. In the last few million years, however, Earth's climate began to cool. Glaciers began forming in Antarctica about 35 million years ago, but the climate there was warm enough for trees to grow until

Earth's plates

Earth's crust is broken into many large slabs called *tectonic plates.* The slow flow of the hot, soft rock in the mantle drags the plates along, causing the continents to move in the directions shown by the arrows. Places where plates spread apart, called *spreading centers,* are shown with arrows pointing in opposite directions. Most of Earth's spreading centers are found beneath oceans.



WORLD BOOK map



WORLD BOOK illustration by John F. Eggert

When two plates collide, one plate may slide under the other. Some of the plate material melts and then rises as magma. When it reaches the surface, it produces a volcano.

about 5 million years ago. By about 2 million years ago, at the beginning of a time called the Pleistocene Epoch, ice had accumulated on other continents as well.

Numerous separate ice advances, periods when ice sheets covered vast areas, occurred during the Pleistocene Ice Age. The advances alternated with periods when the climate was warmer and the ice melted. Geologists analyzing sediment deposits from the North Atlantic Ocean determined that there were at least 20 advances and retreats of ice sheets in the past 2 million years. At least four ice advances were big enough to extend over much of Europe, cover most of Canada, and reach deep into the United States.

The most recent advance of ice began about 70,000 years ago and reached its farthest extent about 18,000 years ago. The vast glaciers and sheets of ice scoured out the basins of the Great Lakes and blocked rivers. So much water was trapped in the form of ice that sea level around Earth dropped as much as 390 feet (120 meters), exposing parts of the present ocean floor.

The most recent ice advance ended about 11,500 years ago. Most scientists believe that Earth is currently in an *interglacial period,* and another ice advance will follow.

Why ice ages occur. Scientists do not fully understand why Earth has ice ages. Most believe that tiny changes in Earth's orbit and axis due to the gravitational pull of other planets play a part. These changes alter the amount of energy received from the sun.

Many scientists also believe that variations in the amount of carbon dioxide in the atmosphere are responsible for long-term changes in the climate. Carbon dioxide, a "greenhouse gas," traps heat from the sun and warms Earth's atmosphere. Most of Earth's carbon dioxide is locked in carbonate rocks, such as limestone and dolomite. Earth's climate today would be much warmer if the carbon dioxide trapped in limestone were released into the atmosphere.

When mountains rich in silicate minerals wear down through weathering and erosion, calcium and magnesium erode from the rocks. These elements are carried to the sea by water. There, living organisms absorb the chemicals and use them to make protective carbonate shells. The organisms eventually die and sink to the bottom to form limestone deposits. This process, called the *carbonate-silicate cycle,* removes carbon dioxide from the atmosphere. With less carbon dioxide in the atmosphere to trap heat from the sun, Earth's climate may cool enough to cause an ice age.

Limestone and dolomite deposits exposed to weathering and erosion return carbon dioxide to the atmosphere and contribute to global warming. In addition, some limestone on the ocean floor can be carried down into Earth's mantle by subduction. Beneath the crust, the limestone breaks down into magma under heat and pressure. The carbon dioxide in the limestone can then return to the atmosphere during volcanic eruptions.

Scientists theorize that volcanoes continued to emit carbon dioxide into the atmosphere during the Precambrian ice ages. Eventually, the carbon dioxide warmed Earth through the greenhouse effect, causing the ice to melt rapidly.

History of Earth

The history of Earth is recorded in the rocks of Earth's crust. Rocks have been forming, wearing away, and reforming ever since Earth took shape. The products of weathering and erosion are called *sediment.* Sediment accumulates in layers known as *strata.* Strata contain clues that tell geologists about Earth's past. These clues include the composition of the sediment, the way the strata are deposited, and the kinds of fossils that may occur in the rock.

Space exploration has expanded our understanding of Earth's origin. The Hubble Space Telescope has observed what appear to be stars in the process of forming planets. Since the mid-1990's, scientists have found other stars that have planets surrounding them. These discoveries have helped scientists develop theories about the formation of Earth.

Age of Earth. Scientists think that Earth probably formed at about the same time as the rest of the solar system. They have determined that some chondrite meteorites, the unaltered remains from the formation of the solar system, are up to 4.6 billion years old. Scientists believe that Earth and other planets are probably that old. They can determine the ages of rocks by measuring the amounts of natural radioactive materials, such as uranium, in them. Radioactive elements *decay* (change into other elements) at a known rate. For example, uranium gives off radiation and decays into lead. Scientists know the time it takes for uranium to change to lead. They can determine the age of a rock by comparing the amount of uranium to the amount of lead.

The known history of Earth is divided into four long stretches of time called *eons.* Starting with the earliest, the eons are Hadean, Archean, Proterozoic, and Phanerozoic. The first three eons, which together lasted nearly 4 billion years, are grouped into a unit called the Precambrian. The Phanerozoic Eon, when life became abundant, is divided into three *eras.* They are, from the oldest to the youngest, the Paleozoic, Mesozoic, and Cenozoic eras. Eras are divided into *periods,* and periods are divided into *epochs.* These divisions and subdivisions are named for places where rocks of each period were studied. Periods are mostly separated by important changes in the types of fossils found in the rocks. As a result, the lengths of eras, periods, and epochs are not equal.

A chart showing an outline of Earth's history is called a *geological time scale.* On such a chart, Earth's earliest history is at the bottom, and its recent history at the top. This arrangement resembles the way rock strata are formed, with the recent over the oldest. A geological time scale appears in the chart *Outline of Earth's history* in this article.

© Leo De Wys

Layers of sedimentary rock called *strata* provide clues to Earth's history. The dark layers here contain iron oxide, evidence that Earth's atmosphere contained oxygen 2 billion years ago.

© James L. Amos, Photo Researchers

Fossils provide clues about the history of life on Earth. This fossil *crinoid* (sea lily) is preserved in limestone that formed during the Jurassic Period, about 140 million years ago.

Formation of Earth. Most scientists believe that the solar system began as a thin cloud of gas and dust in space. The sun itself may have formed from a portion of the cloud that was thicker than the rest. The cloud's own gravity caused it to start contracting, and dust and gas were drawn in toward the center. Much of the cloud collapsed to the center to form a star, the sun, but a great ring of material remained orbiting around the star. Particles in the ring collided to make larger objects, which in turn collided to build up the planets of the solar system in a process called *accretion.* Scientists believe that many small planets formed and then collided to make larger planets.

Earth's early development. Scientists theorize that Earth began as a waterless mass of rock surrounded by a cloud of gas. Radioactive materials in the rock and increasing pressure in Earth's interior produced enough heat to melt the interior of Earth. The heavy materials, such as iron, sank. The light silicate rocks rose to Earth's surface and formed the earliest crust. The heat of the interior caused other chemicals inside Earth to rise to the surface. Some of these chemicals formed water, and others became the gases of the atmosphere.

In 2001, an international team of scientists announced the discovery of a crystal of the mineral *zircon* that they determined to be 4.4 billion years old. Zircon, made up of the elements zirconium, silicon, and oxygen, is a hard, long-lasting mineral that resists erosion and weathering. Through chemical analysis of the zircon, the scientists determined that liquid water probably existed on Earth's surface when the crystal was formed. They concluded that Earth's crust and oceans may have formed within about 200 million years after the planet had taken shape.

Astronomers believe that the sun was about 30 percent fainter when Earth first formed than it is today. The oldest rocks on Earth, however, provide evidence that Earth was warm enough for liquid water to exist on the surface. Scientists believe that the atmosphere must have trapped more heat from the sun than it does today. Over millions of years, the water slowly collected in low places of the crust and formed oceans.

After the main period of planet formation, most of the remaining debris in the solar system was swept up by the newly formed planets. The collisions of the newly formed planets and debris material were explosive. The impacts created the cratered surfaces of the moon, Mars, Venus, and Mercury. Earth was also struck, but

the craters produced by the impacts have all been destroyed by erosion and plate tectonics. Geologists believe that large masses of continental crust had formed by 3.5 billion years ago. There is evidence that plate tectonics has been active for at least 2 billion years.

Some scientists believe Earth's early atmosphere contained hydrogen, helium, methane, and ammonia, much like the present atmosphere of Jupiter. Others believe it may have contained a large amount of carbon dioxide, as does the atmosphere of Venus. Scientists agree that Earth's earliest atmosphere probably had little oxygen.

Geologists have determined that, about 2 billion years ago, a change in Earth's atmosphere occurred. They know that because certain kinds of iron ores created in oxygen-poor environments stopped forming at that time. Instead, large deposits of red sandstone formed. The red color results from iron reacting with oxygen to form *iron oxide,* or rust. The sandstone deposits are evidence that Earth's atmosphere contained some oxygen. The air was not breathable at that time, but the atmosphere may have had about 1 percent oxygen.

The oxygen in the atmosphere today comes mainly from plants and microorganisms such as algae. These organisms use carbon dioxide and give off oxygen through the process of photosynthesis. The amount of oxygen increased in the atmosphere of the early Earth as oxygen-producing organisms developed and became more plentiful.

Life on Earth. Many rocks contain fossils that reveal the history of life on Earth. A fossil may be an animal's body, a tooth, or a piece of bone. It may simply be an impression of a plant or an animal made in a rock when the rock was soft sediment. Fossils help scientists learn which kinds of plants and animals lived at different times in Earth's history. Scientists who study prehistoric life are called *paleontologists.*

Many scientists believe that life appeared on Earth almost as soon as conditions allowed. There is evidence for chemicals created by living things in rocks from the Archean age, 3.8 billion years old. Fossil remains of microscopic living things about 3.5 billion years old have also been found at sites in Australia and Canada.

For most of Earth's history, life consisted mainly of microscopic, single-celled creatures. The earliest fossils of larger creatures with many cells are found in Precambrian rocks that are about 600 million years old. Many of these creatures differed from any living things today.

The Paleozoic Era. Fossils become abundant in Cambrian rocks that are about 544 million to 505 million years old. This apparently sudden expansion in the number of life forms in the fossil record is called the *Cambrian Explosion,* and it marks the beginning of the Paleozoic Era. The Cambrian Explosion actually occurred over tens of millions of years, but it appears sudden in the fossil record. The earliest abundant fossils consist of only a few kinds of organisms. Over the course of hundreds of millions of years, the number of species increases gradually in the fossil record.

Most fossil organisms found in Paleozoic rocks are *invertebrates* (animals without a backbone), such as corals, *mollusks* (clams and snails), and *trilobites* (flat-shelled sea animals). Fish, the earliest *vertebrates* (animals with a backbone), are first found in Ordovician rocks about 450 million years old. Silurian rocks, about 440 million years old, contain fossils of the first large land plants. Amphibians, animals capable of living on land or in the water, first appear as fossils in Devonian rocks about 380 million years old.

Fossil remains preserved in rocks show that by 300 million years ago, large forests and swamps covered the land. The carbon-rich remains of some of these forests are preserved as coal deposits in the United States, Canada, the United Kingdom, and other parts of the world. The Carboniferous Period is named for these enormous deposits of coal.

The earliest fossil remains of reptiles are found in rocks of the Carboniferous Period. Unlike amphibians, reptiles have scaly skins that keep them from drying out, and they lay eggs protected by a shell. These features enable reptiles to live their whole lives out of water. Toward the end of the Paleozoic Era, in rocks from the Permian Period, some fossil reptiles begin to show some characteristics of mammals.

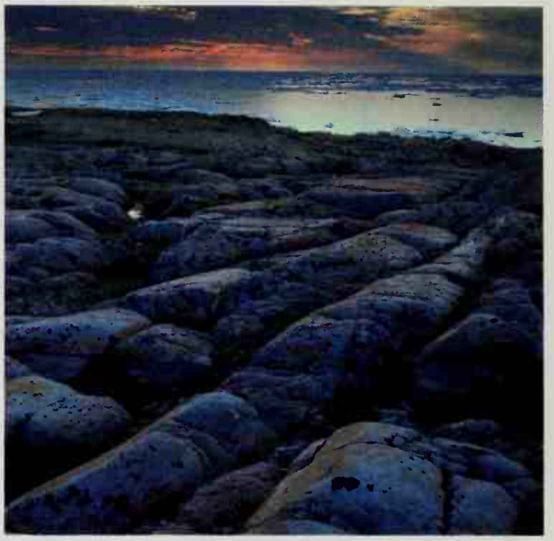
Several times in Earth's history, there have been great *extinctions,* periods when many of Earth's living things die out. The greatest of these events, called the Permian extinction, happened about 250 million years ago. Almost 90 percent of the species on Earth during the Permian became extinct in a relatively short time. The cause of this event is a mystery, though many scientists suspect that huge volcanic eruptions in what is now Siberia may have disturbed the climate, causing many organisms to die out.

The Mesozoic Era. Following the Permian extinction, the fossil record shows that reptiles became the dominant animals on land. The most spectacular of these reptiles were the dinosaurs. The Mesozoic is often called the *Age of the Dinosaurs,* but mammals and birds also appear in the fossil record in rocks from 200 million to 140 million years old.

The oldest materials on Earth are crystals of *zircon,* a hard, durable mineral. In 2001, geologists announced that a single crystal of zircon, found in this piece of sandstone from Australia, was formed about 4.4 billion years ago. Scientists believe that Earth itself formed about 4.6 billion years ago.

WORLD BOOK illustration by Ian Jackson, WILDlife Art

Precambrian time included almost all of Earth's first 4 billion years. The crust, the atmosphere, and the oceans were formed, and the simplest kinds of life appeared.



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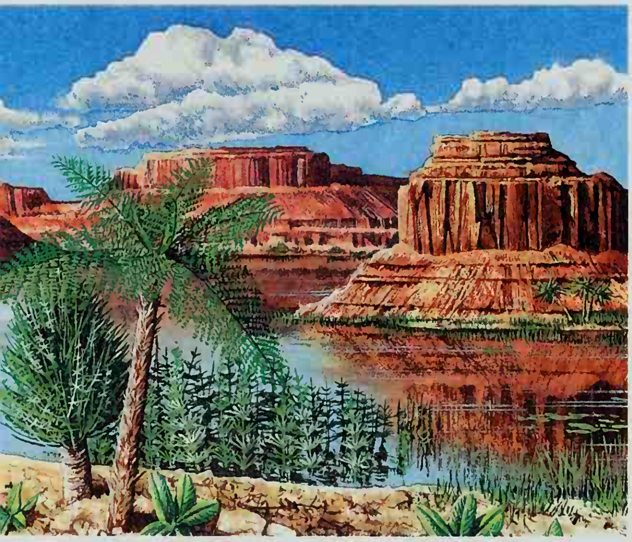
Precambrian rocks exposed on Earth's surface are often highly weathered. This portion of the Canadian Shield, a region of ancient crust near Lake Superior, is about 2.5 billion years old.



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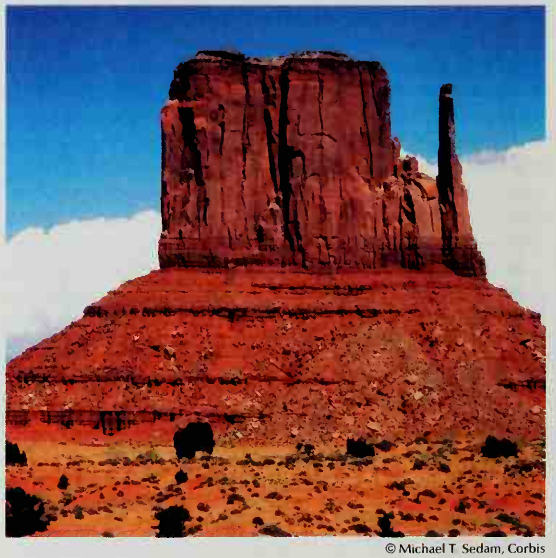
The Paleozoic Era saw the development of many kinds of animals and plants in the seas and on land. The earliest land plants appeared in the Silurian Period, about 440 million years ago.



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Paleozoic sandstones make up part of the rock formations in Monument Valley, Utah. The rocks that once surrounded these formations have been worn away by weathering and erosion.

Fossil plants of the Mesozoic Era represent two main groups, *gymnosperms* and *angiosperms*. Gymnosperms have naked seeds, and most are cone-bearing. They include conifers, ginkgoes, and cycads. These gymnosperms evolved in the late Paleozoic Era and were dominant into the early Cretaceous Period. Angiosperms have covered seeds and are flowering plants. They became the dominant plant group during the Cretaceous Period and continue to be so today.

The dinosaurs died out in another great extinction about 65 million years ago. Most scientists believe that the extinction was caused by the impact of a small asteroid with Earth. The impact would have thrown so much dust into the atmosphere that the surface would have been dark and cold for months, killing off plants and the animals that fed on them. Many scientists believe a large, buried crater in the Yucatan region of Mexico, called Chicxulub *(CHEEK shoo loob)*, is the place the asteroid struck. Debris from the collision has been found all over the world, and deposits created by large sea waves caused by the impact have been found in several places around the Gulf of Mexico.

The Cenozoic Era. The wide variety of plants and animals that we know today came into existence during

WORLD BOOK illustration by Ian Jackson, WILDlife Art

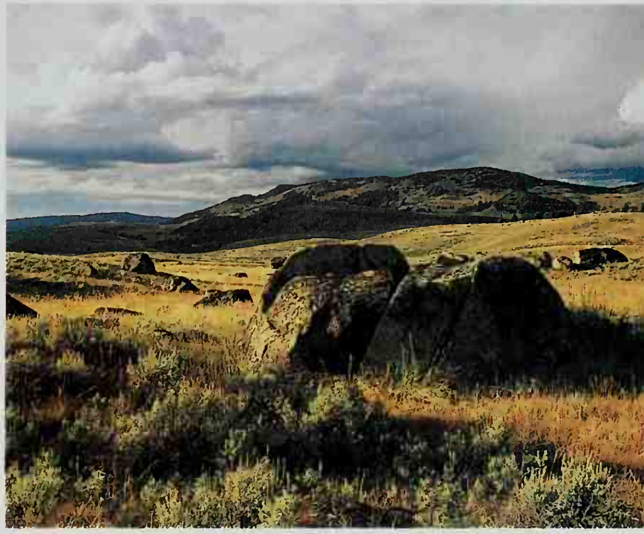
The Mesozoic Era was the Age of Dinosaurs. Plant-eating dinosaurs, such as this *Stegosaurus,* fed on cycads and conifers, early trees that thrived before modern flowering trees appeared.

© Ric Ergenbright Photography

Mesozoic chalk cliffs in Dover, England, formed under warm shallow seas during the Cretaceous Period, late in the Mesozoic. Movement of Earth's crust later pushed the rock above sea level.

WORLD BOOK illustration by Ian Jackson, WILDlife Art

The Cenozoic Era included the Pleistocene Ice Age, when glaciers swept slowly across large areas before melting. The moving ice created a variety of landscapes in northern lands.



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Cenozoic glaciers often carried huge rocks far from their place of origin. Melting ice left these boulders, called *erratics,* on the ground when the Pleistocene age ended thousands of years ago.

the Cenozoic Era. Mammals survived the events that killed off the dinosaurs and expanded to become the dominant land animals of today. The evolutionary history of today's mammals is recorded in the fossil record of the Cenozoic Era.

During the Eocene Epoch, ancestors of the horse, rhinoceros, and camel roamed Europe and North America. By the Oligocene Epoch, dogs and cats had appeared, along with three-toed horses about as large as sheep. The mammals grew larger and developed in greater variety as prairies spread over the land during the Miocene Epoch.

By the Pliocene Epoch, many kinds of mammals had grown to gigantic size. Elephantlike mammoths and mastodons and giant ground sloths roamed the prairies and forests. These animals died out at the end of the Pleistocene Epoch.

Fossils of the first humanlike creatures appeared near the beginning of the Pleistocene Epoch, about 2.4 million years ago. The first true human beings appeared later, perhaps less than 200,000 years ago. Humanity's years on Earth are only a brief moment among the billions of years during which Earth has developed.

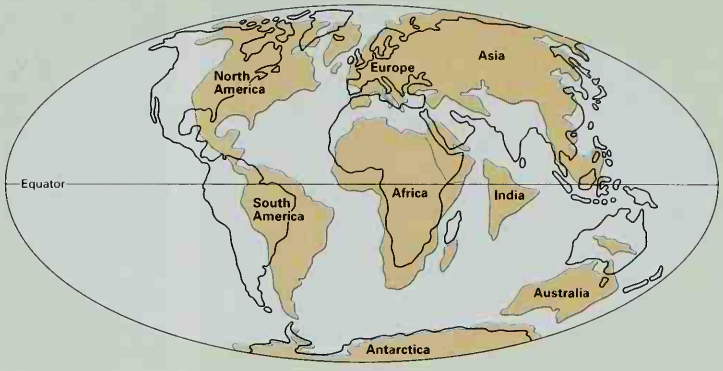
Steven I. Dutch

Outline of Earth's history

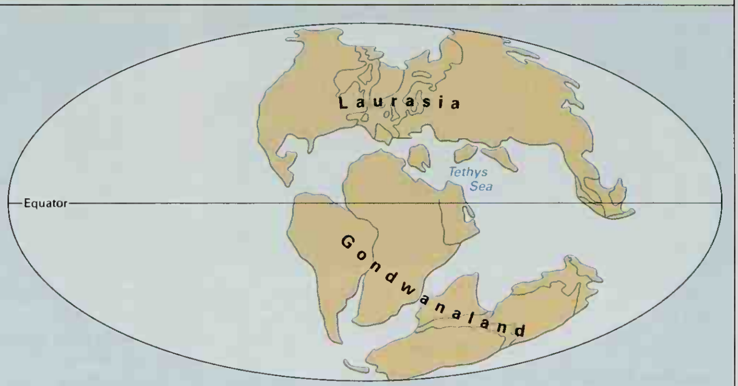
This geological time scale outlines the development of Earth and of life on Earth. Earth's earliest history appears at the bottom of the chart, and its most recent history is at the top.

Era	Period	Period or epoch and its length	Beginning (years ago)	Development of life on Earth	
Cenozoic Era	Quaternary Period	Holocene Epoch 11 $\frac{1}{2}$ thousand years	11 $\frac{1}{2}$ thousand	Human beings hunted and tamed animals; developed agriculture; learned to use metals, coal, oil, gas, and other resources; and put the power of wind and rivers to work.	Cultivated plants
Cenozoic Era	Quaternary Period	Pleistocene Epoch 2 million years	2 million	Modern human beings developed. Mammoths, woolly rhinos, and other animals flourished but died out near the end of the epoch.	Human beings
Cenozoic Era	Tertiary Period	Pliocene Epoch 3 million years	5 million	Sea life became much like today's. Birds and many mammals became like modern kinds and spread around the world. Humanlike creatures appeared.	Horses
Cenozoic Era	Tertiary Period	Miocene Epoch 19 million years	24 million	Apes appeared in Asia and Africa. Other animals included bats, monkeys, and whales, and primitive bears and raccoons. Flowering plants and trees resembled modern kinds.	Apes
Cenozoic Era	Tertiary Period	Oligocene Epoch 10 million years	34 million	Primitive apes appeared. Camels, cats, dogs, elephants, horses, rhinos, and rodents developed. Huge rhinoceroslike animals disappeared near the end of the epoch.	Early horses
Cenozoic Era	Tertiary Period	Eocene Epoch 21 million years	55 million	Birds, amphibians, small reptiles, and fish were plentiful. Primitive bats, camels, cats, horses, monkeys, rhinoceroses, and whales appeared.	Grasses
Cenozoic Era	Tertiary Period	Paleocene Epoch 10 million years	65 million	Flowering plants became plentiful. Invertebrates, fish, amphibians, reptiles, and mammals were common.	Small mammals
Mesozoic Era		Cretaceous Period 80 million years	145 million	Flowering plants appeared. Invertebrates and amphibians were plentiful. Many fish resembled modern kinds. Dinosaurs with horns and armor became common. Dinosaurs died out.	Flowering plants
Mesozoic Era		Jurassic Period 68 million years	213 million	Cone-bearing trees were plentiful. Sea life included shelled squid. Dinosaurs reached their largest size. The first birds appeared. Mammals were small and primitive.	Birds
Mesozoic Era		Triassic Period 35 million years	248 million	Cone-bearing trees were plentiful, as were fish and insects. The first turtles, crocodiles, and dinosaurs appeared, as did the first mammals.	Dinosaurs
Paleozoic Era		Permian Period 38 million years	286 million	The first seed plants—cone-bearing trees—appeared. Fish, amphibians, and reptiles were plentiful.	Seed plants
Paleozoic Era	Carboniferous Period	Pennsylvanian Period 39 million years	325 million	Scale trees, ferns, and giant scouring rushes were abundant. Fish and amphibians were plentiful. The first reptiles appeared. Giant insects lived in forests where coal later formed.	Reptiles
Paleozoic Era	Carboniferous Period	Mississippian Period 35 million years	360 million	Trilobites had nearly died out. Crustaceans, fish, and amphibians were plentiful. Many coral reefs were formed.	Amphibians
Paleozoic Era		Devonian Period 50 million years	410 million	The first forests grew in swamps. Many kinds of fish, including sharks, armored fish, and lungfish, swam in the sea and in fresh waters. The first amphibians and insects appeared.	Fish
Paleozoic Era		Silurian Period 30 million years	440 million	Spore-bearing land plants appeared. Trilobites and mollusks were common. Coral reefs formed.	Corals
Paleozoic Era		Ordovician Period 65 million years	505 million	Trilobites, corals, and mollusks were common. Tiny animals called graptolites lived in branching *colonies* (groups).	Graptolites
Paleozoic Era		Cambrian Period 39 million years	544 million	Fossils were plentiful for the first time. Shelled animals called trilobites, and some mollusks, were common in the sea. Jawless fish appeared.	Trilobites
Precambrian Time Almost 4 billion years (?)			4 $\frac{1}{2}$ billion (?)	Coral, jellyfish, and worms lived in the sea about 1,100 million years ago. Bacteria lived as long as 3 $\frac{1}{2}$ billion years. Before that, no living things are known.	Bacteria

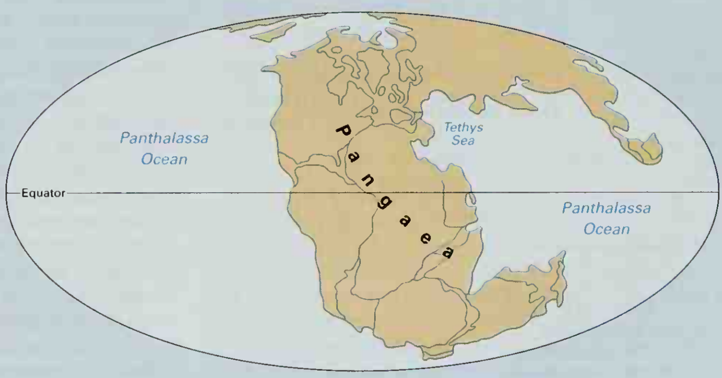
60 million years ago
Paleocene Epoch
Earth scientists believe that the positions of Earth's land masses are continually shifting. The map at the right shows the locations of the continents about 60 million years ago. At that time, the individual continents were approaching their present positions, which are shown in black outline.



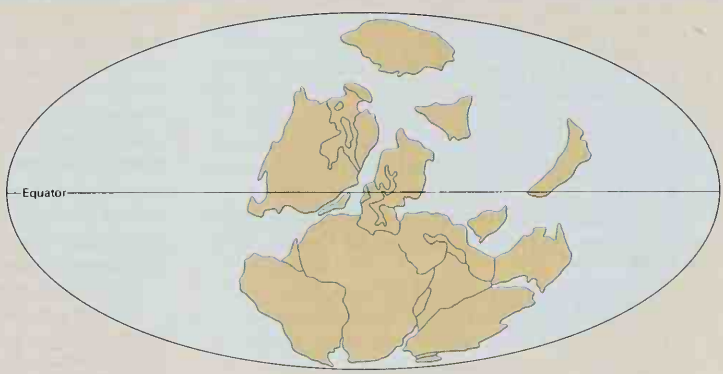
120 million years ago
Cretaceous Period
Scientists theorize that the continents were formed by the breakup of two great land masses: (1) Laurasia to the north, and (2) Gondwanaland to the south. In the map at the right, these two land masses are shown as they may have appeared about 120 million years ago. Laurasia eventually broke up to form Eurasia and North America. Gondwanaland separated into Africa, Antarctica, Australia, India, and South America.



180 million years ago
Jurassic Period
Scientists believe that Laurasia and Gondwanaland were formed by the breakup of a single giant land mass call Pangaea, *right.* This huge land mass was surrounded by a single ocean called Panthalassa. Scientists theorize that Pangaea started breaking apart to form Laurasia and gondwanaland about 200 million years ago.



360 million years ago
Mississippian Period
Little is known about the position of Earth's land before 200 million years ago. Some scientists theorize that a number of land masses came together to form Pangaea. The map at the right shows possible positions of such land masses about 360 million years ago.



WORLD BOOK maps. Based on University of Chicago Paleographic Atlas Project.

Related articles in *World Book*. See Geology and its list of *Related articles*. See also the following articles:

Earth as a planet

Equator
Geography
Geophysics
Map
North Pole
Pole
Solar system
South Pole

Motions and forces of Earth

Climate
Earthquake
Equinox
Erosion
Flood
Glacier
Gravitation
Magnetism (The magnetism of the earth)
Plate tectonics
Season
Volcano

The atmosphere

Air
Carbon dioxide
Global warming
Greenhouse effect
Meteor
Stratosphere
Weather
Wind

The hydrosphere

Hydrology
Hydrosphere
Lake
Ocean
Ooze
River
Water

The lithosphere

Carbonate
Continent
Island
Lava
Mantle
Mineral
Mountain
Rock
Soil

Earth history

Cretaceous Period
Devonian Period
Dinosaur
Fossil
Ice age
Paleontology
Plant (Early plants)
Pleistocene Epoch
Prehistoric animal
Prehistoric people

Other related articles

Gaia
Life
Moon
Planet
Sun
Universe

Outline

I. **Earth as a planet**
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B. Earth's size and shape
C. Earth and its moon
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C. Terrane collisions
D. Earthquakes
E. The shaping of the continents
VII. **Earth's changing climate**
A. The ice ages
B. Why ice ages occur
VIII. **History of Earth**

Questions

What two elements make up most of the rocks in Earth's crust?
What is the difference between a day and a sidereal day?
Where is the Earth-moon barycenter located?
How does Earth rank in size among the planets?
What gas makes up most of Earth's atmosphere?
What possible outcomes can occur when two of Earth's plates collide?
What is the biosphere?
During what geological period were most of Earth's coal deposits formed?
What are the major differences between continental crust and oceanic crust?
How can erosion contribute to global warming?

Additional resources

Level I
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Earth Day is an annual observance, held on April 22, to increase public awareness of environmental problems. Each year on Earth Day, millions of people throughout the world gather to clean up litter, to protest threats to the environment, and to celebrate progress in reducing pollution.

Earth Day began in the United States. In 1969, U.S. Senator Gaylord A. Nelson suggested that a day of environmental education be held on college campuses. The following year, the lawyer and environmentalist Denis Hayes, then a recent graduate of Stanford University, led hundreds of students in planning and organizing the observance of Earth Day on April 22, 1970. About 20 million people participated in this celebration.

The observance of Earth Day in 1970 helped alert people to the dangers of pollution and stimulated a new environmental movement. That same year, the United States Congress created the Environmental Protection Agency to set and enforce pollution standards. Congress also passed the Clean Air Act of 1970, which limited the amount of air pollution that cars, utilities, and industries could release. Other new environmental laws soon followed. Denis Hayes

Earth science is the study of the earth and its origin and development. It deals with the makeup and structure of the earth and with its atmosphere and waters. Earth science combines such related fields as geology, meteorology, oceanography, and physical geography.

Maria Luisa Crawford

Related articles in *World Book* include:

Earth
Geochemistry
Geology
Geophysics
Hydrology
Meteorology
Ocean
Paleontology
Plate tectonics

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Park Snavely, U.S. Geological Survey

Earthquakes are among the most destructive and powerful forces in nature. An Iranian, *left,* mourns the damage caused by a 1990 quake. The course of a stream, *right,* was changed by shifting rock along the San Andreas Fault. Such rock shifts can cause devastating quakes.

Earthquake

Earthquake is a shaking of the ground caused by the sudden breaking and shifting of large sections of the earth's rocky outer shell. Earthquakes are among the most powerful events on earth, and their results can be terrifying. A severe earthquake may release energy 10,000 times as great as that of the first atomic bomb. Rock movements during an earthquake can make rivers change their course. Earthquakes can trigger landslides that cause great damage and loss of life. Large earthquakes beneath the ocean can create a series of huge, destructive waves called *tsunamis* (pronounced *tsoo NAH meez*) that flood coasts for many miles.

Earthquakes almost never kill people directly. Instead, many deaths and injuries result from falling objects and the collapse of buildings, bridges, and other structures. Fire resulting from broken gas or power lines is another major danger during a quake. Spills of hazardous chemicals are also a concern during an earthquake.

The force of an earthquake depends on how much rock breaks and how far it shifts. Powerful earthquakes can shake firm ground violently for great distances. During minor earthquakes, the vibration may be no greater than the vibration caused by a passing truck.

On average, a powerful earthquake occurs less than once every two years. At least 40 moderate earthquakes cause damage somewhere in the world each year. Scientists estimate that more than 8,000 minor earthquakes occur each day without causing any damage. Of those, only about 1,100 are strong enough to be felt.

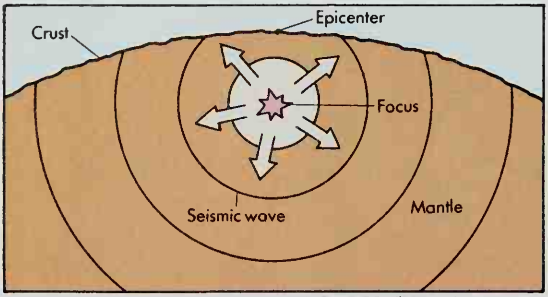
Karen C. McNally, the contributor of this article, is Professor of Earth Sciences and Director of the Charles F. Richter Seismological Laboratory at the University of California at Santa Cruz.

How an earthquake begins

Most earthquakes occur along a *fault*—a fracture in the earth's rocky outer shell where sections of rock repeatedly slide past each other. Faults occur in weak areas of the earth's rock. Most faults lie beneath the surface of the earth, but some, like the San Andreas Fault in California, are visible on the surface. Stresses in the earth cause large blocks of rock along a fault to *strain,* or bend. When the stress on the rock becomes great enough, the rock breaks and snaps into a new position, causing the shaking of an earthquake.

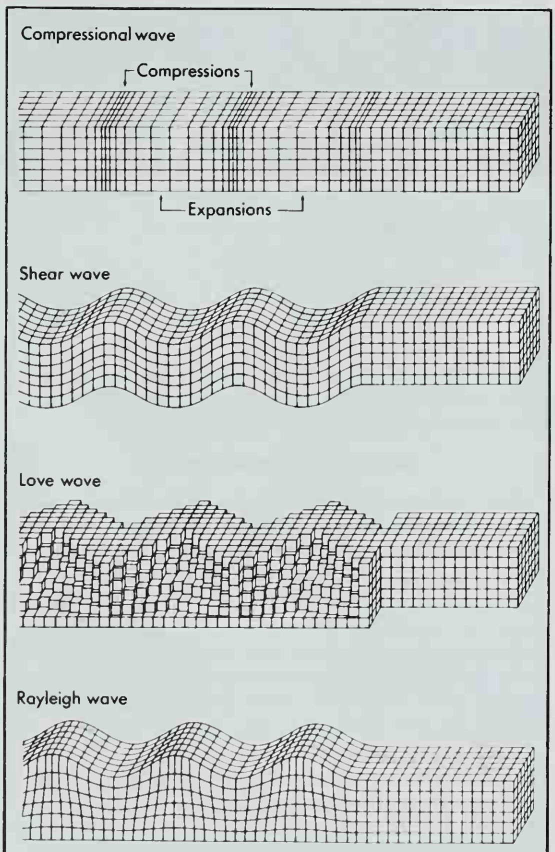
Earthquakes usually begin deep in the ground. The point in the earth where the rocks first break is called the *focus,* also known as the *hypocenter,* of the quake. The focus of most earthquakes lies less than 45 miles (72 kilometers) beneath the surface, though the deepest known focuses have been nearly 450 miles (700 kilometers) below the surface. The point on the surface of the earth directly above the focus is known as the *epicenter* of the quake. The strongest shaking is usually felt near the epicenter.

From the focus, the break travels like a spreading crack along the fault. The speed at which the fracture spreads depends on the type of rock. It may average about 2 miles (3.2 kilometers) per second in granite or other strong rock. At that rate, a fracture may spread



WORLD BOOK illustration by Doug DeWitt

An earthquake occurs when the earth's rock suddenly breaks and shifts, releasing energy in vibrations called *seismic waves.* The point in the earth where the rock first breaks is called the *focus.* The point on the surface above is known as the *epicenter.*



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Different seismic waves travel through rock in different ways. A *compressional wave* travels through the earth, compressing and expanding the rock. When a compressional wave hits the surface, it can cause houses and other structures to contract and expand. A *shear wave* also travels through the earth, moving rock back and forth. At the earth's surface, it can shake structures violently. A *Love wave* travels along the earth's surface and moves the ground from side to side. A *Rayleigh wave* also travels through the rock at the earth's surface, making the surface roll like waves on the ocean.

more than 350 miles (560 kilometers) in one direction in less than three minutes. As the fracture extends along the fault, blocks of rock on one side of the fault may drop down below the rock on the other side, move up and over the other side, or slide forward past the other.

How an earthquake spreads

When an earthquake occurs, the violent breaking of rock releases energy that travels through the earth in the form of vibrations called *seismic waves.* Seismic waves move out from the focus of an earthquake in all directions. As the waves travel away from the focus, they grow gradually weaker. For this reason, the ground generally shakes less farther away from the focus.

There are two chief kinds of seismic waves: (1) body waves and (2) surface waves. Body waves, the fastest seismic waves, move through the earth. Slower surface waves travel along the surface of the earth.

Body waves tend to cause the most earthquake damage. There are two kinds of body waves: (1) compressional waves and (2) shear waves. As the waves pass through the earth, they cause particles of rock to move in different ways. Compressional waves push and pull the rock. They cause buildings and other structures to contract and expand. Shear waves make rocks move from side to side, and buildings shake. Compressional waves can travel through solids, liquids, or gases, but shear waves can pass only through solids.

Compressional waves are the fastest seismic waves, and they arrive first at a distant point. For this reason, compressional waves are also called *primary (P) waves.* Shear waves, which travel slower and arrive later, are called *secondary (S) waves.*

Body waves travel faster deep within the earth than near the surface. For example, at depths of less than 16 miles (25 kilometers), compressional waves travel at about 4.2 miles (6.8 kilometers) per second, and shear waves travel at 2.4 miles (3.8 kilometers) per second. At a depth of 620 miles (1,000 kilometers), the waves travel more than $1\frac{1}{2}$ times that speed.

Surface waves are long, slow waves. They produce what people feel as slow rocking sensations and cause little or no damage to buildings.

There are two kinds of surface waves: (1) Love waves and (2) Rayleigh waves. Love waves travel through the earth's surface horizontally and move the ground from side to side. Rayleigh waves make the surface of the earth roll like waves on the ocean. Typical Love waves travel at about $2\frac{3}{4}$ miles (4.4 kilometers) per second, and Rayleigh waves, the slowest of the seismic waves, move at about $2\frac{1}{4}$ miles (3.7 kilometers) per second. The two types of waves were named for two British physicists, Augustus E. H. Love and Lord Rayleigh, who mathematically predicted the existence of the waves in 1911 and 1885, respectively.

Damage by earthquakes

How earthquakes cause damage. Earthquakes can damage buildings, bridges, dams, and other structures, as well as many natural features. Near a fault, both the shifting of large blocks of the earth's crust, called *fault slippage,* and the shaking of the ground due to seismic waves cause destruction. Away from the fault, shaking produces most of the damage. Undersea earthquakes

may cause huge tsunamis that swamp coastal areas. Other hazards during earthquakes include rockfalls, ground settling, and falling trees or tree branches.

Fault slippage. The rock on either side of a fault may shift only slightly during an earthquake or may move several feet or meters. In some cases, only the rock deep in the ground shifts, and no movement occurs at the earth's surface. In an extremely large earthquake, the ground may suddenly heave 20 feet (6 meters) or more. Any structure that spans a fault may be wrenched apart. The shifting blocks of earth may also loosen the soil and rocks along a slope and trigger a landslide. In addition, fault slippage may break down the banks of rivers, lakes, and other bodies of water, causing flooding.

Ground shaking causes structures to sway from side to side, bounce up and down, and move in other violent ways. Buildings may slide off their foundations, collapse, or be shaken apart.

In areas with soft, wet soils, a process called *liquefaction* may intensify earthquake damage. Liquefaction occurs when strong ground shaking causes wet soils to behave temporarily like liquids rather than solids. Anything on top of liquefied soil may sink into the soft ground. The liquefied soil may also flow toward lower ground, burying anything in its path.

Tsunamis. An earthquake on the ocean floor can give a tremendous push to surrounding seawater and create one or more large, destructive waves called tsunamis, also known as *seismic sea waves.* Some people call tsunamis *tidal waves,* but scientists think the term is misleading because the waves are not caused by the tide. Tsunamis may build to heights of more than 100 feet (30 meters) when they reach shallow water near shore. In the open ocean, tsunamis typically move at speeds of 500 to 600 miles (800 to 970 kilometers) per hour. They can travel great distances while diminishing little in size and can flood coastal areas thousands of miles or kilometers from their source.

Structural hazards. Structures collapse during a quake when they are too weak or rigid to resist strong, rocking forces. In addition, tall buildings may vibrate wildly during an earthquake and knock into each other.

A major cause of death and property damage in earthquakes is fire. Fires may start if a quake ruptures gas or power lines. The 1906 San Francisco earthquake ranks as one of the worst disasters in United States history because of a fire that raged for three days after the quake (see **San Francisco** [Earthquake and fire]).

Other hazards during an earthquake include spills of toxic chemicals and falling objects, such as tree limbs, bricks, and glass. Sewage lines may break, and sewage may seep into water supplies. Drinking of such impure water may cause cholera, typhoid, dysentery, and other serious diseases.

Loss of power, communication, and transportation after an earthquake may hamper rescue teams and ambulances, increasing deaths and injuries. In addition, businesses and government offices may lose records and supplies, slowing recovery from the disaster.

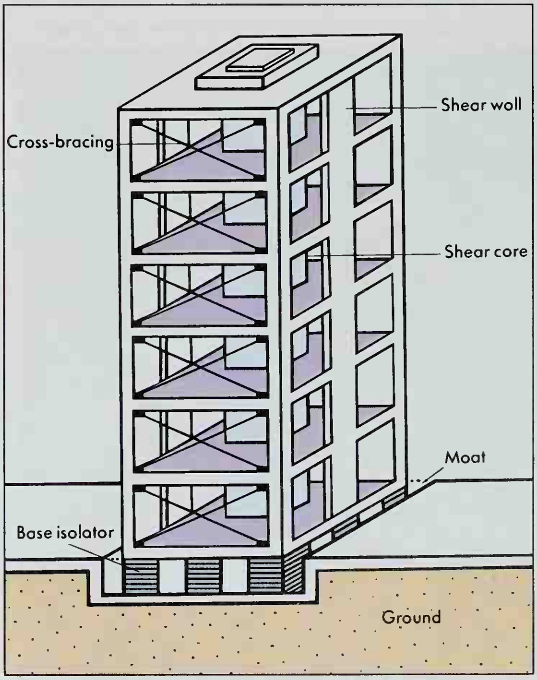
Reducing earthquake damage. In areas where earthquakes are likely, knowing where to build and how to build can help reduce injury, loss of life, and property damage during a quake. Knowing what to do when a quake strikes can also help prevent injuries and deaths.

Where to build. Earth scientists try to identify areas that would likely suffer great damage during an earthquake. They develop maps that show fault zones, *flood plains* (areas that get flooded), areas subject to landslides or to soil liquefaction, and the sites of past earthquakes. From these maps, land-use planners develop zoning restrictions that can help prevent construction of unsafe structures in earthquake-prone areas.

How to build. Engineers have developed a number of ways to build earthquake-resistant structures. Their techniques range from extremely simple to fairly complex. For small- to medium-sized buildings, the simpler reinforcement techniques include bolting buildings to their foundations and providing support walls called *shear walls.* Shear walls, made of *reinforced concrete* (concrete with steel rods or bars embedded in it), help strengthen the structure and help resist rocking forces. Shear walls in the center of a building, often around an elevator shaft or stairwell, form what is called a *shear core.* Walls may also be reinforced with diagonal steel beams in a technique called *cross-bracing.*

Builders also protect medium-sized buildings with devices that act like shock absorbers between the building and its foundation. These devices, called *base isolators,* are usually bearings made of alternate layers of steel and an elastic material, such as synthetic rubber. Base isolators absorb some of the sideways motion that would otherwise damage a building.

Skyscrapers need special construction to make them earthquake-resistant. They must be anchored deeply and securely into the ground. They need a reinforced framework with stronger joints than an ordinary sky-



WORLD BOOK illustration by Doug DeWitt

An earthquake-resistant building includes such structures as *shear walls,* a *shear core,* and *cross-bracing. Base isolators* act as shock absorbers. A moat allows the building to sway.

scraper has. Such a framework makes the skyscraper strong enough and yet flexible enough to withstand an earthquake.

Earthquake-resistant homes, schools, and workplaces have heavy appliances, furniture, and other structures fastened down to prevent them from toppling when the building shakes. Gas and water lines must be specially reinforced with flexible joints to prevent breaking.

Safety precautions are vital during an earthquake. People can protect themselves by standing under a doorframe or crouching under a table or chair until the shaking stops. They should not go outdoors until the shaking has stopped completely. Even then, people should use extreme caution. A large earthquake may be followed by many smaller quakes, called *aftershocks.* People should stay clear of walls, windows, and damaged structures, which could crash in an aftershock.

People who are outdoors when an earthquake hits should quickly move away from tall trees, steep slopes, buildings, and power lines. If they are near a large body of water, they should move to higher ground.

Where and why earthquakes occur

Scientists have developed a theory, called *plate tectonics,* that explains why most earthquakes occur. According to this theory, the earth's outer shell consists of about 10 large, rigid plates and about 20 smaller ones. Each plate consists of a section of the earth's crust and a portion of the *mantle,* the thick layer of hot rock below the crust. Scientists call this layer of crust and upper mantle the *lithosphere.* The plates move slowly and continuously on the *asthenosphere,* a layer of hot, soft rock in the mantle. As the plates move, they collide, move apart, or slide past one another.

The movement of the plates strains the rock at and near plate boundaries and produces zones of faults around these boundaries. Along segments of some faults, the rock becomes locked in place and cannot slide as the plates move. Stress builds up in the rock on both sides of the fault and causes the rock to break and shift in an earthquake. See **Plate tectonics.**

There are three types of faults: (1) normal faults, (2) reverse faults, and (3) strike-slip faults. In normal and reverse faults, the fracture in the rock slopes downward, and the rock moves up or down along the fracture. In a normal fault, the block of rock on the upper side of the sloping fracture slides down. In a reverse fault, the rock on both sides of the fault is greatly compressed. The compression forces the upper block to slide upward and the lower block to thrust downward. In a strike-slip fault, the fracture extends straight down into the rock, and the blocks of rock along the fault slide past each other horizontally.

Most earthquakes occur in the fault zones at plate boundaries. Such earthquakes are known as *interplate earthquakes.* Some earthquakes take place within the interior of a plate and are called *intraplate earthquakes.*

Interplate earthquakes occur along the three types of plate boundaries: (1) mid-ocean spreading ridges, (2) subduction zones, and (3) transform faults.

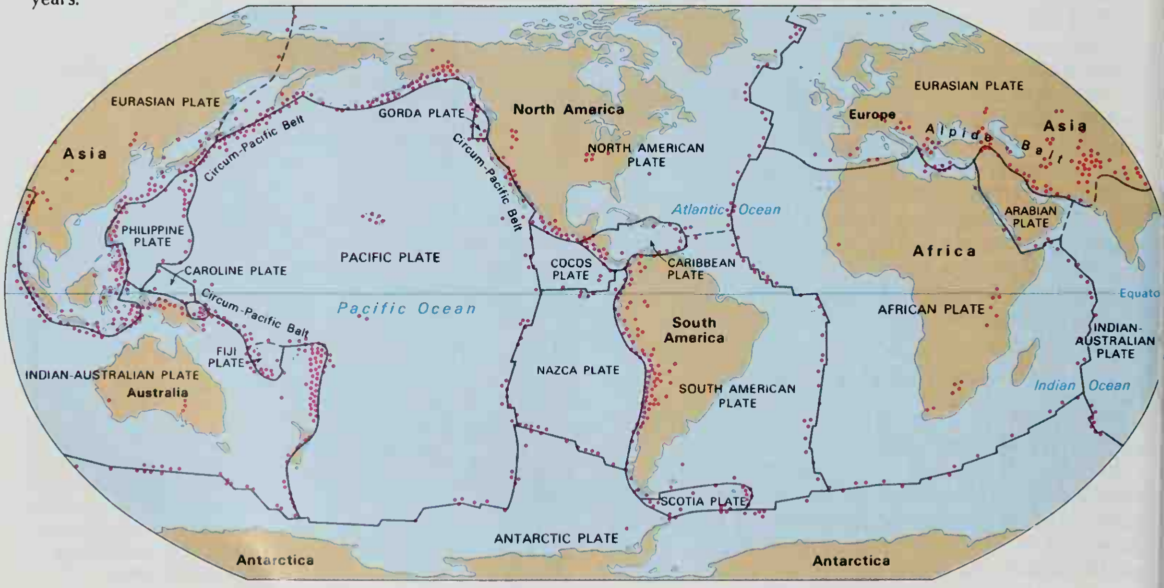
Mid-ocean spreading ridges are places in the deep ocean basins where the plates move apart. As the plates separate, hot lava from the earth's mantle rises between them. The lava gradually cools, contracts, and cracks, creating faults. Most of these faults are normal faults. Along the faults, blocks of rock break and slide down away from the ridge, producing earthquakes.

Near the spreading ridges, the plates are thin and weak. The rock has not cooled completely, so it is still somewhat flexible. For these reasons, large strains cannot build, and most earthquakes near spreading ridges are shallow and mild or moderate in severity.

Where earthquakes occur

Most earthquakes occur near and along the boundaries of the rocky plates that cover the earth's surface. Each dot on the map represents a major earthquake that occurred during the past 30 years.

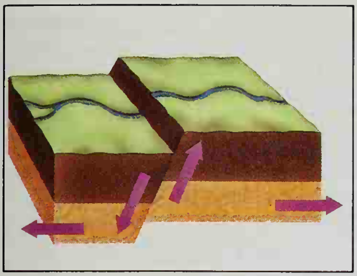
WORLD BOOK map



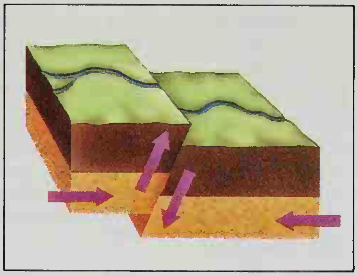
Types of faulting

Movement of the earth called *faulting* causes most earthquakes. In *normal faulting, left,* two blocks of earth move apart and one drops down. In *reverse faulting, center,* two blocks collide and one is pushed under the other. In *strike-slip faulting, right,* the blocks slide past each other.

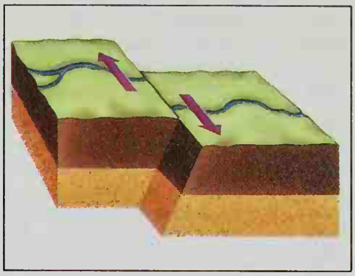
WORLD BOOK illustration by Sarah Woodward



Normal faulting



Reverse faulting



Strike-slip faulting

Subduction zones are places where two plates collide, and the edge of one plate pushes beneath the edge of the other in a process called *subduction.* Because of the compression in these zones, many of the faults there are reverse faults. About 80 per cent of major earthquakes occur in subduction zones encircling the Pacific Ocean. In these areas, the plates under the Pacific Ocean are plunging beneath the plates carrying the continents. The grinding of the colder, brittle ocean plates beneath the continental plates creates huge strains that are released in the world's largest earthquakes.

The world's deepest earthquakes occur in subduction zones down to a depth of about 450 miles (700 kilometers). Below that depth, the rock is too warm and soft to break suddenly and cause earthquakes.

Transform faults are places where plates slide past each other horizontally. Strike-slip faults occur there. Earthquakes along transform faults may be large, but not as large or deep as those in subduction zones.

One of the most famous transform faults is the San Andreas Fault. The slippage there is caused by the Pacific Plate moving past the North American Plate. The San Andreas Fault and its associated faults account for most of California's earthquakes. See **San Andreas Fault.**

Intraplate earthquakes are not as frequent or as large as those along plate boundaries. The largest intraplate earthquakes are about 100 times smaller than the largest interplate earthquakes.

Intraplate earthquakes tend to occur in soft, weak areas of plate interiors. Scientists believe intraplate quakes may be caused by strains put on plate interiors by changes of temperature or pressure in the rock. Or the source of the strain may be a long distance away, at a plate boundary. These strains may produce quakes along normal, reverse, or strike-slip faults.

Studying earthquakes

Recording, measuring, and locating earthquakes. To determine the strength and location of earthquakes, scientists use a recording instrument known as a *seismograph.* A seismograph is equipped with sensors called *seismometers* that can detect ground motions caused by seismic waves from both near and distant earthquakes. Some seismometers are capable of detecting ground motion as small as 1 billionth of a meter, or about 40 billionth of an inch. See **Seismograph.**

Scientists called *seismologists* measure seismic ground movements in three directions: (1) up-down, (2) north-south, and (3) east-west. The scientists use a separate sensor to record each direction of movement.

A seismograph produces wavy lines that reflect the size of seismic waves passing beneath it. The record of the wave, called a *seismogram,* is imprinted on paper, film, or recording tape or is stored and displayed by computers.

Probably the best-known gauge of earthquake intensity is the *local Richter magnitude scale,* developed in 1935 by United States seismologist Charles F. Richter. This scale, commonly known as the *Richter scale,* measures the ground motion caused by an earthquake. Every

© Doug Wechsler, Earth Scenes

A seismologist examines the record of vibrations from a quake as registered by an instrument called a *seismograph.*

Largest earthquakes

This table lists the largest earthquakes since 1900. Magnitude is given using the moment magnitude scale, which measures large earthquakes more accurately than the conventional Richter scale. For a list of the earthquakes that have caused the most deaths, see **Disaster** (table).

Year	Location	Magnitude	Year	Location	Magnitude
1905	Northern Mongolia	8.5	**1958**	Kuril Islands	8.7
	Northwestern Mongolia	8.4	**1960**	Southern Chile	9.5
1906	Pacific Ocean floor, near Ecuador	8.8	**1963**	Kuril Islands	8.6
	Central Chile	8.2	**1964**	Southern Alaska	9.2
1917	Western Samoa	8.5	**1965**	Aleutian Islands	8.7
1920	Central China	8.3	**1966**	Western Peru	8.2
1922	Central Chile	8.5	**1968**	Pacific Ocean floor, near Japan	8.3
1923	Kamchatka Peninsula, Russia	8.5	**1977**	Sumbawa Island, Indonesia	8.2
1924	Macquarie Island, Australia	8.3	**1979**	Northwestern Ecuador	8.3
1933	Pacific Ocean floor, near Japan	8.4	**1989**	South Pacific Ocean floor, near Macquarie Island, Australia	8.2
1938	Banda Sea floor, near Indonesia	8.5			
1950	Arunachal Pradesh, India	8.6	**1994**	Kuril Islands	8.3
1952	Kamchatka Peninsula, Russia	9.0		Northwestern Bolivia	8.2
1957	Aleutian Islands	9.1	**2000**	Papua New Guinea	8.0
	Northern Mongolia	8.1	**2001**	Western Peru	8.4

Source: U.S. Geological Survey.

increase of one number in magnitude means the energy release of the quake is about 32 times greater. For example, an earthquake of magnitude 7.0 releases about 32 times as much energy as an earthquake measuring 6.0. An earthquake with a magnitude of less than 2.0 is so slight that usually only a seismometer can detect it. A quake greater than 7.0 may destroy many buildings. The number of earthquakes increases sharply with every decrease in Richter magnitude by one unit. For example, there are 8 times as many quakes with magnitude 4.0 as there are with magnitude 5.0. See **Richter magnitude.**

Although large earthquakes are customarily reported on the Richter scale, scientists prefer to describe earthquakes greater than 7.0 on the *moment magnitude scale.* The moment magnitude scale measures more of the ground movements produced by an earthquake. Thus, it describes large earthquakes more accurately than does the Richter scale.

The largest earthquake ever recorded on the moment magnitude scale measured 9.5. It was an interplate earthquake that occurred along the Pacific coast of Chile in South America in 1960. The largest intraplate earthquakes known struck in central Asia and in the Indian Ocean in 1905, 1920, and 1957. These earthquakes had moment magnitudes between about 8.0 and 8.3. The largest intraplate earthquakes in the United States were three quakes that occurred in New Madrid, Missouri, in 1811 and 1812. The earthquakes were so powerful that they changed the course of the Mississippi River. During the largest of them, the ground shook from southern Canada to the Gulf of Mexico and from the Atlantic Coast to the Rocky Mountains. Scientists estimate the earthquakes had moment magnitudes of 7.5.

Scientists locate earthquakes by measuring the time it takes body waves to arrive at seismographs in a minimum of three locations. From these wave arrival times, seismologists can calculate the distance of an earthquake from each seismograph. Once they know an earthquake's distance from three locations, they can find the quake's focus at the center of those three locations.

Predicting earthquakes. Scientists can make fairly accurate long-term predictions of where earthquakes will occur. They know, for example, that about 80 percent of the world's major earthquakes happen along a belt encircling the Pacific Ocean. This belt is sometimes called the Ring of Fire because it has many volcanoes, earthquakes, and other geologic activity.

Scientists are working to make accurate forecasts on when earthquakes will strike. Geologists closely monitor certain fault zones where quakes are expected. Along these fault zones, they can sometimes detect small quakes, the tilting of rock, and other events that might signal a large earthquake is about to occur.

Exploring the earth's interior. Most of what is known about the internal structure of the earth has come from studies of seismic waves. Such studies have shown that rock density increases from the surface of the earth to its center. Knowledge of rock densities within the earth has helped scientists determine the probable composition of the earth's interior.

Scientists have found that seismic wave speeds and directions change abruptly at certain depths. From such studies, geologists have concluded that the earth is composed of layers of various densities and substances. These layers consist of the crust, mantle, outer core, and inner core. Shear waves do not travel through the outer core. Because shear waves cannot travel through liquids, scientists believe the outer core is liquid. Scientists believe the inner core is solid because of the movement of compressional waves when they reach the inner core.

Karen C. McNally

Related articles in *World Book* include:

Outline

V. Studying earthquakes
- A. Recording, measuring, and locating earthquakes
- B. Predicting earthquakes
- C. Exploring the earth's interior

Questions

Why do buildings collapse during an earthquake?
How do earthquakes help scientists learn about the earth's interior?
Where do the world's largest and deepest earthquakes occur?
What is a seismograph?
Why do earthquakes occur?
What should people do to be safe during an earthquake?
What type of seismic waves tend to cause the most damage?
What is the Richter scale? The moment magnitude scale?
How do scientists determine the location of an earthquake?
What is liquefaction? A tsunami?

Additional resources

Bolt, Bruce A. *Earthquakes.* 4th ed. W. H. Freeman, 1999.
Lay, Thorne, and Wallace, T. C. *Modern Global Seismology.* Academic Pr., 1995.
Ritchie, David. *The Encyclopedia of Earthquakes and Volcanoes.* Facts on File, 1994.
Sutherland, Lin. *Earthquakes and Volcanoes.* Reader's Digest, 2000. Younger readers.

Earthworm, also called *night crawler,* is a name used for many kinds of common worms found in moist, warm soil throughout the world. The earthworm is a well-known fishing bait, and it is sometimes called a *fishworm* or *angleworm.*

Earthworms contribute to the growth of plants. The worms help break down the *humus* (decaying matter in the soil). The soil is loosened and mixed as the earthworm burrows through the ground. Worms are also important food for birds.

Earthworms range in size from only $\frac{1}{25}$ inch (1 millimeter) long to up to 11 feet (3 meters) long. They have a smooth, reddish-brown body made up of rings called *annuli.* The body is built like two tubes, one inside the other. The inner one is the digestive tube. The outer one is the body wall. Earthworms have no eyes or ears, but they have a mouth and can sense heat, light, and touch.

A worm crawls by lengthening its front part and pushing through the soil, then pulling the hind part up. A worm's body wall has two kinds of muscles that it uses to crawl. Circular muscles surround the body and can make it shrink or spread out. Longitudinal muscles run the length of the body and can shorten or lengthen the worm. *Setae* (bristles) prevent the worm from slipping.

The earthworm has no lungs or gills. It breathes through its thin skin, which is in contact with the air between the particles of soil. If the weather becomes too dry and warm, a worm will die. Earthworms feed on dead plant material found in the soil. This is why some people say an earthworm eats its way through the soil.

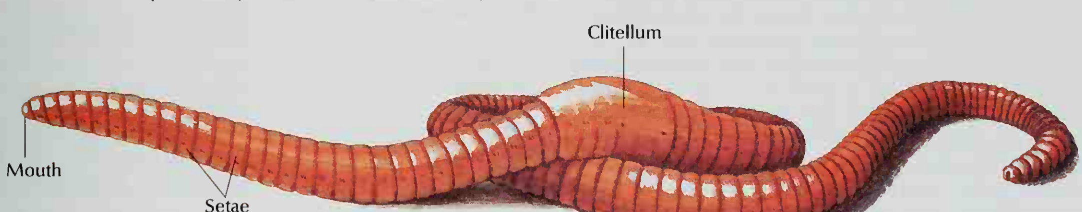
An earthworm is a *hermaphrodite*—that is, an animal that has both male and female reproductive organs. However, each worm must mate with another worm to form eggs. After mating, eggs are laid in a cufflike structure that surrounds the body of the earthworm. The *clitellum,* a few large annuli of the body, produces this cuff for the eggs. As the earthworm moves, the cuff slides along the body and over the head. It closes completely around the eggs to make a sacklike *cocoon.* After several weeks in the cocoon, the young earthworms hatch. David F. Oetinger

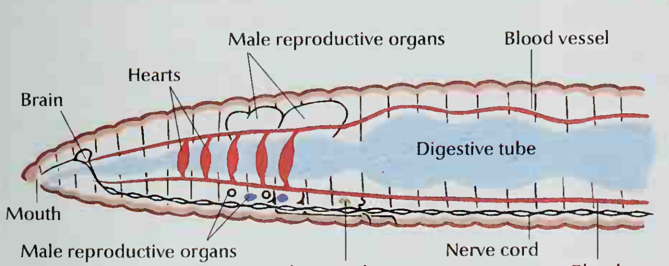
Scientific classification. Earthworms are in the family Lumbricidae of the segmented worm phylum, Annelida. The scientific name for one common species of earthworm is *Lumbricus terrestris.*

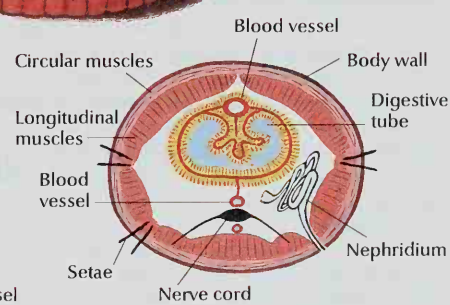
See also Brain (In invertebrates).

Earwig is an insect that has a large pair of pincers at the rear of its body. Earwigs may be found under stones, in decayed bark of trees, and in moist places. They come out and are most active at night. Most earwigs measure from $\frac{1}{4}$ to 1 inch (0.6 to 2.5 centimeters) in length.

Earthworm The earthworm's body is made up of segments. On each segment, except the first and last, are four pairs of tiny bristles called *setae* that help the worm move through the earth.







WORLD BOOK diagrams by Margaret Estey

An earthworm has five pairs of "hearts" in the front part of its body. The "hearts" help circulate the worm's blood.

A worm's waste matter is given off by organs called *nephridia,* which function like human kidneys.

Earwigs have a hard, shiny body covering. Their upper wings are short and leathery, while the lower ones appear gauzelike. Their heads carry long, delicate feelers, called *antennae.* These insects live worldwide but are most common in tropical and subtropical regions. About 20 *species* (kinds) live in the United States.

Earwigs may destroy fruit and flowers, but they aid farmers by eating thrips, snails, and caterpillars. Most native American species are harmless. The *European earwig* damages crops. This species has spread to North America. Earwigs are named from the belief that they enter a sleeping person's ear. Sandra J. Glover

Scientific classification. The European earwig is in the family Forficulidae. It is *Forficula auricularia.* The *small earwig* common to the United States is in the family Labiidae. It is *Labia minor.*

See also **Insect** (picture: Familiar kinds of insects).

East, in international relations. See **Cold War.**

East Germany. See **Germany** (History).

East India Company was the name of several European companies that opened trade with India and the Far East in the 1600's. East India companies were private enterprises given charters by the governments of England, the Netherlands, Denmark, and France. The companies received special trading rights from their governments. The English (later British) East India Company had the longest life—nearly 260 years—and the greatest influence. It opened India and the Far East to English trade and eventually brought India into the British Empire.

Before 1600, Portugal controlled most European trade with India and the Far East. The English company was formed in 1600 and soon began competing with the Portuguese. The Dutch company was formed in 1602, the Danish company in 1616, and the French company in 1664. During the 1600's, the Dutch and English companies seized most of the Portuguese holdings and drove most of the Portuguese traders out of India. The Dutch gained control of the islands that became the Dutch East Indies (now part of Indonesia).

To protect itself, the English company made agreements with the rulers of India during the 1600's. It carried on trade without trying to acquire territory. But in the early 1700's, the Mughal Empire, which had ruled India and given it political unity for about 200 years, began to break up. Many regional states emerged, and fighting often broke out among them. The English and French tried to improve their positions in India by intervening in Indian politics and taking sides in local disputes. In the 1740's and 1750's, the French tried to win control of India, but the British, under Robert Clive, stopped them. French influence in India ended in the early 1800's, when the French were at war in Europe. British influence then spread quickly, without French interference.

Legislation passed by the Dutch government in 1798 caused the Dutch company, deep in debt, to disband the following year. In 1845, the Danish holdings in India were sold to the British company. The British company ruled India until the Indian Rebellion, a revolt led by Indian troops from 1857 to 1859. In 1858, as a result of the revolt, the British government took control of India from the East India Company. Alan W. Cafruny

See also **Clive, Robert; India** (History); **Indian Rebellion; Dutch East India Company; Raffles, Sir Thomas Stamford.**

East Indies, in its widest sense, refers to southeastern Asia, including India, Myanmar (formerly Burma), Thailand, Laos, Cambodia, and Vietnam; the islands around the Malay Archipelago; and the Philippines. In a narrower sense, the term *East Indies* is used to mean only the islands of the Malay Archipelago. The Republic of Indonesia, formerly the *Netherlands Indies,* forms part of this island group.

The term *Indies,* or *Ind,* was first used in the 1400's. Christopher Columbus thought he was finding a short route to the rich Indies when he landed in America. He therefore called the islands the *Caribbean Indies.* Later, these islands were named the *West Indies* and the Pacific islands were called the *East Indies,* to distinguish the two groups. Harold Crouch

See also **Southeast Asia.**

East Pakistan. See **Bangladesh.**

East Roman Empire. See **Byzantine Empire; Rome, Ancient** (Decline and fall; map: Division of the Roman Empire).

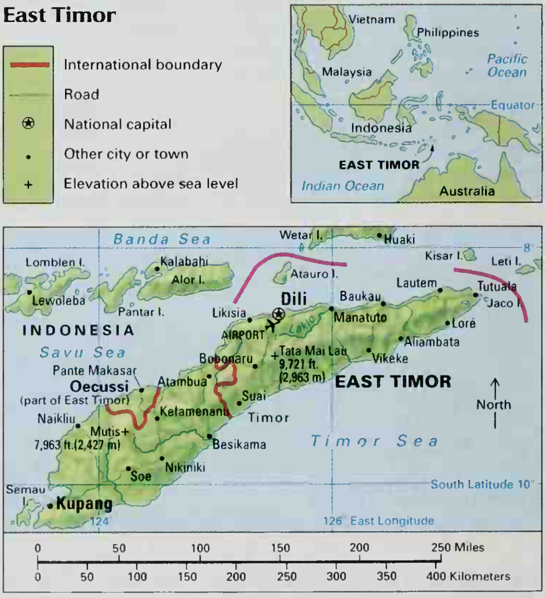
East Sea. See **Japan, Sea of.**

East Timor, *TEE mawr* or *tee MAWR,* is a small country in Southeast Asia. It occupies the eastern side of the island of Timor. This island lies in the Timor Sea, about 300 miles (480 kilometers) north of Australia. Dili is East Timor's capital and largest city. The country's official name is the Democratic Republic of East Timor.

Portugal began trading in East Timor during the 1500's and gradually established control of the region. After the Portuguese withdrew in 1975, Indonesia invaded and occupied East Timor. In 1999, the East Timorese voted overwhelmingly for independence. That same year, the United Nations (UN) began administering East Timor and helping it prepare for full independence. East Timor became independent on May 20, 2002.

Government. East Timor is a republic with a multiparty political system. The president, who is head of state and supreme commander of the armed forces, is elect-

East Timor



WORLD BOOK maps

East Timorese fishermen haul in their nets on a beach near Dili, the country's capital. Fishing and agriculture are important economic activities in East Timor.

© Julio Etchar, The Image Works

ed by the people to a five-year term. The prime minister is chosen by members of the National Parliament, the nation's legislature, to head the government. Like the president, members of the National Parliament are elected to five-year terms. The Supreme Court of Justice is the nation's highest court.

East Timor is divided into 13 districts for purposes of local government. Each one is headed by a district administrator and a district council.

People. East Timor's two official languages are Tetum and Portuguese. But more than a dozen local languages are spoken, as well as Bahasa Indonesia and English. Although the East Timorese belong to a number of separate ethnic groups, most of the people are of Malay or Melanesian ancestry. Some East Timorese are descendants of Portuguese settlers.

About 90 percent of the people are Roman Catholics, and the Catholic Church plays a central role in cultural and political life. Some East Timorese practice variations of traditional religions along with Catholicism.

Land. East Timor consists of the eastern side of the island of Timor, the region of Oecussi in western Timor, and the two small islands of Atauro and Jaco. Indonesia occupies the rest of the island of Timor. Much of East Timor's land is rugged and mountainous. But the coastal plains in the south and parts of the north are fertile.

Daytime temperatures average about 75 °F (24 °C) throughout the year, with cooler temperatures at higher altitudes. Monsoon winds produce distinct wet and dry seasons. In the north, the wet season normally lasts from December to April. Rainfall is typically higher, and the wet season longer, in the south.

Economy. East Timor is one of the poorest countries in Southeast Asia. Agriculture is the country's leading economic activity. The principal export is coffee. Important local industries include fishing, *market gardening* (raising fruits and vegetables to sell directly to the public), and marble mining. Oil and gas deposits off the coast of East Timor have not yet been developed.

History. People have lived on the island of Timor for thousands of years. Sandalwood from Timor was traded throughout Asia in ancient times.

In the 1500's, Portugal began to trade with the people of Timor. Portugal gradually gained control of the eastern part of the island in the 1600's and 1700's. Meanwhile, the Netherlands gained control of the western part of the island and most of what is now Indonesia. In 1859, Portugal and the Netherlands agreed to divide the island under the Treaty of Lisbon. East Timor became a colony of Portugal, called Portuguese Timor, in 1896.

In 1942, during World War II, Japan occupied Timor. In 1945, at the end of the war, control of East Timor returned to Portugal.

In 1975, Portugal withdrew from East Timor and a brief civil war erupted. One of the parties in the conflict, the Revolutionary Front for an Independent East Timor (FRETILIN), declared East Timor's independence in November 1975. In December, Indonesia, which already possessed the western part of the island, sent military troops to take control of the eastern section. In July 1976, Indonesia annexed East Timor as its 27th province, but its authority there was never accepted by the UN.

Many in East Timor resisted Indonesian rule. During this period, as many as 200,000 East Timorese died, many from starvation and disease. In the 1990's, the United States and other nations joined nongovernmental organizations in accusing Indonesia of human rights violations. In 1996, Carlos Ximenes Belo, the Roman Catholic Bishop of Dili, and José Ramos-Horta, the international spokesman for the independence movement, won the Nobel Peace Prize for their efforts to secure a just settlement of the conflict.

In 1999, Indonesia proposed that the East Timorese should vote on whether they favored independence or a form of *autonomy* (self-government) under Indonesian rule. Almost 80 percent of East Timor's people voted for independence in the referendum, which took place in August 1999. After the vote, opponents of independence, assisted by the Indonesian armed forces, launched a campaign of terror against the East Timorese. The violence left at least 1,000 people dead and destroyed much of East Timor's *infrastructure* (public buildings, roads, and utilities). At least 250,000 residents were forced into refugee camps in Indonesia.

In September 1999, the UN sent an Australian-led multinational military force to East Timor to stop the violence. In October, Indonesia's legislature voted to end

Facts in brief

Capital: Dili
Official languages: Portuguese and Tetum.
Area: 5,706 mi^2 (14,874 km^2). *Greatest distances*—north-south, 96 mi (154 km); east-west, 228 mi (367 km).
Elevation: *Highest*—Tata Mai Lau, 9,721 ft (2,963 m). *Lowest*—sea level.
Population: *Estimated 2002 population*—911,000; density, 159 per mi^2 (61 per km^2).
Chief products: coffee, fish, forest products.
Flag: The flag has a small black triangle within a larger yellow triangle at the staff. A white star is in the middle of the black triangle. The rest of the flag is red. See **Flag** (picture: Flags of Asia and the Pacific).
Money: *Basic unit*—United States dollar.

Indonesia's claim to the territory. The UN, together with East Timorese leaders, began administering the region.

In 2001, 16 political parties competed in elections for an 88-member Constituent Assembly. The Assembly completed and approved a new constitution in early 2002. Following independence, it became the country's first parliament. In April 2002, the long-time resistance leader José Alexandre Gusmão, commonly known as Xanana Gusmão, was elected president by the people of East Timor. Full political power was transferred to the new government on May 20. Geoffrey Robinson

Easter is the most important Christian festival of the year. Easter celebrates the return to life of Jesus Christ, the founder of Christianity, after His Crucifixion. Jesus's return to life is called the *Resurrection.* The Gospels tell that on the morning two days after Jesus's death, His tomb was found empty. Soon, Jesus's followers began to see Him and talk with Him. Christians believe Jesus's Resurrection means that they, too, can receive new life after death. The Easter festival celebrates this belief.

Most Christians observe Easter on the first Sunday after the first full moon following the first day of spring in the Northern Hemisphere. Thus, the festival can occur on any Sunday between March 22 and April 25. In the Eastern Orthodox Churches, the celebration of Easter may take place later because these churches use additional factors in calculating the date of the festival.

The Easter festival is closely associated with spring. The new plant life that appears in spring symbolizes the new life Christians gain because of Jesus's Crucifixion and Resurrection. The word *Easter* may have come from an early English word, *Eastre.* Some scholars say Eastre was the name of a pagan goddess of spring, the name of a spring festival, or the name of the season itself. Other scholars believe the word *Easter* comes from the early German word *eostarun,* which means *dawn.* This word may be an incorrect translation of the Latin word *albae,* meaning both *dawn* and *white.* Easter was considered a day of "white" because newly baptized church members wore white clothes at Easter observances.

Christians in many European countries call Easter *Pascha.* This word comes from the Hebrew word *pesah,* which means *passover.* Jesus was celebrating the Jewish festival of Passover shortly before He was arrested and sentenced to be crucified. Passover recalls how God rescued the Jews from slavery in ancient Egypt (see **Passover**). Christians believe that Easter, like Passover, is a time of rescue. They say that by His death and Resurrection, Jesus rescued them from eternal death and punishment for their sins.

Religious observances of Easter

Easter is the center of an entire season of the Christian year. The first part of the season is *Lent,* a period of about 40 days before Easter Sunday. Some churches exclude Sundays, and others exclude Saturdays and Sundays, from this period. During Lent, Christians prepare for Easter. They consider it a time for *penance*—that is, a time to show sorrow for sins and to seek forgiveness. One common form of Lenten penance for Christians is fasting, which limits the kinds or the amounts of food that are eaten. Christians patterned Lent after the 40 days Jesus prayed and fasted in the wilderness to prepare for teaching and leading His people. Easter Sunday is followed by a 50-day period ending on *Pentecost,* the seventh Sunday after Easter. Pentecost is a festival in memory of the descent of the Holy Spirit upon the apostles.

The beginning of Lent. In Western churches, Lent begins on Ash Wednesday. Many churches, especially Roman Catholic, Anglican, and Lutheran, hold special services on this day. This service often includes the blessing of ashes on the foreheads of worshipers, and words based on Genesis 3:19, "for dust thou art, and unto dust shalt thou return." The ceremony reminds participants that they should begin their Lenten penance in a humble spirit.

In the Eastern Orthodox Churches, members attend an evening service on the Sunday before Ash Wednesday. This Sunday is sometimes called *Forgiveness Sunday* because at the end of the service worshipers ask the priest and one another for forgiveness for their sins. Lent officially begins in the Eastern Orthodox Churches on the next day, called *Pure Monday.*

Holy Week is the final week of Lent. Some churches hold special services every day of the week. Holy Week recalls the events leading to Jesus's death and Resurrection. For more information about these events, see **Jesus Christ** (The Passion).

Palm Sunday is the first day of Holy Week. It celebrates the story of Jesus's triumphal entry into Jerusalem, where people spread palm branches and clothing before Him. During Palm Sunday services, many churches distribute cut palm leaves, sometimes woven into the shape of a cross. Greek Orthodox Christians receive branches of fragrant bay leaves. The leaves are then used in cooking during the year.

Maundy Thursday, also called *Holy Thursday,* recalls Jesus's last meal and His arrest and imprisonment. Many Protestant churches hold Communion services on this day. During Maundy Thursday Mass, Roman Catholic priests often wash the feet of 12 church members or poor people in remembrance of how Jesus washed the feet of His 12 disciples at the time of the final meal. A priest takes the *Host* (the wafer of bread regarded as Jesus's body) from the main altar to a shrine on the side. The shrine symbolizes the place where Jesus was held

Robert Harding Picture Library

Palm Sunday begins Holy Week. This street procession in Mexico City commemorates Jesus's triumphal entry into Jerusalem, when people spread palm branches before Him.

prisoner after His arrest. All decorations are removed from the main altar as a symbol of the stripping of Jesus's garments before the Crucifixion.

Good Friday observes the death of Jesus on the cross. Most churches hold mourning services. Some services last from noon until 3 p.m. to symbolize the last three hours of darkness while Jesus suffered on the cross. The Eastern Orthodox Churches follow services with ceremonies recalling how Jesus was taken from the cross and placed inside a tomb. In many Spanish-speaking countries, Christians hold processions in which people carry statues of the dying Jesus and His mother, Mary. Many Christians eat little or no food on Good Friday.

Holy Saturday is chiefly a day of solemn *vigil* (watch). The major activity of the day comes at nightfall as observance of the Resurrection approaches. Roman Catholic and Eastern Orthodox churches hold vigil services that often include the baptism of new members. The vigil service leads up to a dramatic moment. The lights in each church are put out, leaving everyone in darkness. Then, the priest lights one tall candle, representing the risen Jesus. The flame from this candle is used to light other candles held by worshipers, which symbolizes the spreading of Jesus's light throughout the world. In Eastern Orthodox Churches, the ceremony is timed so that the priest lights his candle exactly at midnight. After all the candles have been lit, the service becomes an Easter celebration, with joyous music and the reading of the Easter story from the Bible. Traditionally, newly converted Christians were baptized on this day, after having received religious instruction during Lent.

Easter Sunday celebrates the Resurrection of Jesus. Roman Catholic and Eastern Orthodox churches hold Saturday evening services, but most Protestant churches wait until Sunday morning to hold their main Easter services. Many churches and communities, particularly in the United States, have additional outdoor Easter services at sunrise. At that time, the light of the rising sun recalls the light that comes back to the world with the newly risen Jesus. Catholic and Orthodox churches also hold additional services on Easter Sunday, especially for those who missed the long services of the preceding night. For many Christians, Easter Sunday is set aside for feasting and celebration.

Fresco (early 1460's) by Piero della Francesca; Editorial Photocolor Archives

The Resurrection is the central event in the celebration of the Christian festival of Easter. This Italian Renaissance painting shows the risen Jesus with one foot on His tomb. He holds a flag that symbolizes His authority over humanity.

Blair Seitz, Editorial Photocolor Archives

Good Friday marks the death of Jesus. This parade held in the Philippines reenacts how Jesus carried His cross through the streets of Jerusalem to the hill where He was crucified.

The end of the Easter season. During the 40-day period beginning with Easter Sunday, Christians celebrate the time when Jesus reappeared to some of His followers. This period ends on Ascension Day, or Ascension Thursday. On this day, the story of Jesus's rise to heaven is read in churches. In Catholic churches, the Easter paschal candle is put out on Ascension Day. The Easter season concludes 10 days later with the feast of Pentecost, when the apostles reported that the Holy Spirit had entered into them. Christians believe that the church began at that time.

Easter symbols

Many symbols remind Christians of the original Easter events and their meaning. Most of these symbols are used only during the Easter season. The rest are part of Christian life and worship throughout the year.

The crucifix and the cross are present in churches and many homes throughout the year. A crucifix is a cross with an image of Jesus's body hanging from it. It symbolizes the sacrifice Jesus made by allowing Himself to be killed. An empty cross—that is, without the figure of Christ crucified—reminds Christians of Jesus's victory over death and the new life and hope this victory brings to believers.

Sunday is an Easter symbol that is also observed the year around. Christians traditionally worship on Sunday because that day is associated with the Resurrection.

Candles are burned during many Easter celebrations, especially the vigil and midnight services before Easter Sunday. Christians associate Jesus with the light from candles, calling Him "the Light of the World." Many churches extinguish candles on their altars on Good Fri-

day to show that Jesus's light has gone out. In Roman Catholic churches, the special paschal candle is lit on Easter Sunday next to the main altar. The candle represents Jesus's return to life. The candle is often lit during the next 40 days, until it is put out on Ascension Day.

Easter lilies are used to decorate churches and homes. The large, pure white blossoms remind Christians of the pure new life that comes to them through the Resurrection of Jesus.

Eggs and rabbits are the only familiar symbols unrelated to the Easter story. Eggs, which represent new life, have been a symbol of spring since ancient times. Christians adopted the egg as an Easter symbol because of the relationship between Easter and the renewal of life. Rabbits are associated with the fertility of spring because of their ability to produce many young. Some parents tell their children that the Easter Rabbit, or Easter Bunny, brings Easter eggs.

The lamb is a particularly important Easter symbol in central and eastern European countries. It represents Jesus and relates His death to that of the lamb sacrificed on the first Passover. Christians traditionally refer to Jesus as "the Lamb of God." Many people serve lamb as part of the Easter feast. In many homes, a lamb-shaped cake decorates the table. Many Eastern Orthodox Christians hang pictures of the Easter lamb in their homes.

Other foods. Besides lamb and eggs, certain other foods are associated with the Easter season. Pretzels, for example, were originally a Lenten food. Their twisted shape suggested arms crossed in prayer. Hot cross buns, now eaten throughout the Easter season, were first baked in England to be served on Good Friday. The buns have a cross made of icing on the top.

Easter customs

A number of popular customs are observed during the Easter season. Some are followed by most Christians. Others are observed in a particular area or by a particular group.

Carnivals provide opportunities for feasting and merrymaking before the solemn fast days of Lent. The word *carnival* comes from the Latin word *carnelevarium,* which means *removal of meat.* The most famous carnival is the Mardi Gras, celebrated on Shrove Tuesday, the day before Lent begins. *Mardi Gras* is a French term that means *Fat Tuesday.* It refers to the fat ox that traditionally led a procession on Shrove Tuesday in France. Carnivals often feature parades in which people wear elaborate costumes. The best-known Mardi Gras parade in North America takes place in New Orleans.

Easter eggs. Exchanging and eating Easter eggs is a popular custom in many countries. In most cases, chicken eggs are used. The eggs are hard-boiled and dyed in various colors and patterns. Many countries have their own traditional patterns. Probably the most famous Easter eggs are those designed in Ukraine and Poland, where Christians decorate the eggs with complicated red, black, and white patterns.

In many countries, children hunt for Easter eggs hidden about the home. Children in the United Kingdom, Germany, and some other countries play a game in which eggs are rolled against one another or down a hill. The egg that stays uncracked the longest wins. Since 1878, children in Washington, D.C., have been invited to roll eggs on the White House lawn.

Passion Plays dramatize the Easter story. Such plays have been performed during the Easter season since the Middle Ages. The most famous one is usually presented every 10 years in Oberammergau, in southern Germany. It dates from 1634. In the United States, Passion Plays are performed annually in several cities.

Feasting. Easter Sunday is a feast day. Many Christians in eastern Europe and those of eastern European ancestry in North America have their Easter feast blessed by a priest. The priest may go to the home, or families may take their food to church for the blessing.

Wearing new clothes for Easter is a custom common among many Christians. It may have originated from the old practice of having newly baptized Christians wear new white clothes for the Easter celebration. Like many other Easter symbols, the new clothes represent the new life offered through the death and Resurrection of Jesus.

Easter promenades of people in new clothes are a tradition in many European towns and villages. Some of these promenades are led by a person holding a cross or an Easter candle. In New York City, thousands of people stroll in the Easter Parade down Fifth Avenue to show off their new clothes following Easter services.

Other customs. Many communities follow customs of the Easter season that are special to them. In Bethlehem, Pennsylvania, for example, a trombone choir of the Moravian Church plays hymns throughout the city before dawn on Easter Sunday to call church members to a sunrise service in the old Moravian cemetery. At the cemetery, the trombones play a joyful chorus as the sun appears on the horizon. Nancy E. Auer Falk

Related articles in *World Book* include:

Ash Wednesday	Lent	Passion Play
Easter lily	Mardi Gras	Pentecost
Good Friday	Maundy Thursday	Resurrection
Holy Week	Palm Sunday	Shrove Tuesday
Jesus Christ		

Additional resources

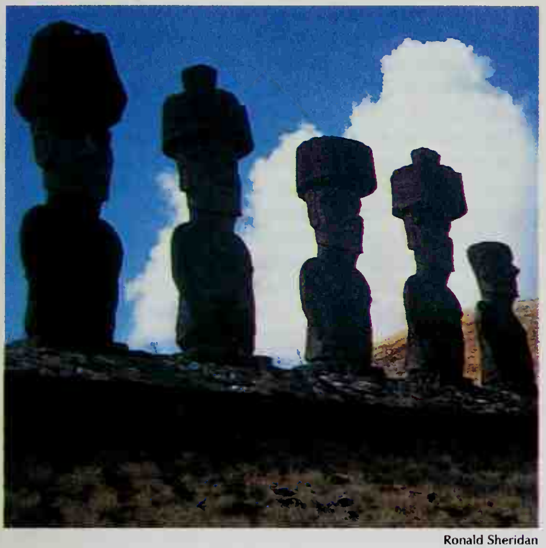
Kennedy, Pamela. *An Easter Celebration: Traditions and Customs from Around the World.* Ideals Children's Bks., 1991. Younger readers.

National Gallery of Art. *The Easter Story.* Bulfinch, 1993.

Easter Island, in the South Pacific Ocean, is famous as the site of enormous statues of people that were carved hundreds of years ago. The island lies about 2,300 miles (3,700 kilometers) west of Chile. For location, see **Pacific Islands** (map). Easter Island has been governed by Chile since 1888.

Easter Island covers 64 square miles (166 square kilometers). Its soil is stony. The only fresh water comes from wells, *tanks* (pools), and crater lakes in the island's three extinct volcanoes. About 2,000 people live on the island. Most of the people are Polynesians. The rest are Chileans. Spanish—the language of Chile—is the official language. But both Spanish and a Polynesian language called *Rapanui* (pronounced *RAH puh NOO ee*) are spoken. Easter Island's Spanish name is Isla de Pascua. Its Polynesian name is Rapanui. Tourism and the production of wool for export are the main industries.

Scientists believe that Easter Island was settled about A.D. 400, but they are not sure who the first inhabitants were. Some say they were American Indians, and others



Ronald Sheridan

Huge stone statues on Easter Island were carved hundreds of years ago. More than 600 of them are scattered on the island. Some of the statues rise as high as 40 feet (12 meters).

believe they were Polynesians.

The early islanders created the famous statues, which are called *moai* (*MOH eye*). The statues were possibly intended to honor ancestors. Today, more than 600 statues are scattered on the island. Most are from 11 to 20 feet (3.4 to 6 meters) tall. Some rise as high as 40 feet (12 meters) and weigh as much as 90 tons (82 metric tons). The islanders used stone hand picks to carve the statues from the rock of an extinct volcano. They set up the statues on raised temple platforms called *ahu.* Huge red stone cylinders were balanced on the heads of some of the statues, like hats. Even today, erecting such large statues and balancing the cylinders on top of them would be a difficult feat.

A bloody war between two groups of Easter Islanders broke out about 1680. During the following period of about 150 years, the victors in the war and their descendants toppled the moai from their platforms, in most cases breaking the necks of the statues. About 15 moai have been restored to their original positions.

Jacob Roggeveen, a Dutch explorer, was the first European to see Easter Island. He discovered it on Easter Sunday, 1722, and gave the island its name. In 1862, slave ships from Peru arrived. Their crews kidnapped about 1,400 Easter Islanders and brought them to Peru to work on plantations. All but 100 of these islanders died in Peru. The survivors were taken back to Easter Island in 1863. During the voyage home, 85 islanders died. The 15 survivors carried home the germs of smallpox and other diseases, which spread to remaining islanders. Many of the islanders died from the diseases.

During the early 1870's, many Easter Islanders left their homeland. In 1877, only 110 people remained there. Since then, the native population has grown and Chileans have moved to the island. Robert Langdon

Easter lily is a flower that has become a sign of Easter. It is a tall plant with long, pointed leaves. The large, fragrant, trumpet-shaped flowers are a waxy white color.

Easter lilies grow throughout the world. American florists formerly grew the Madonna lily of southern Europe. Its periods of blooming, however, are not regular. New kinds of Easter lilies have been brought to America from China, Japan, and Bermuda. The Bermuda Easter lily blooms early. The Chinese and Japanese lilies are the hardiest flowers. These lilies bloom outdoors in June or July. Florists can force Chinese and Japanese lilies to bloom just before Easter by growing them in greenhouses. James S. Miller

Scientific classification. Easter lilies belong to the family Liliaceae. The scientific name for a commonly grown type is *Lilium longiflorum,* variety *eximium.*

See also Lily.

Eastern Catholic Churches are a group of independent but related Christian churches in eastern Europe, Africa, and Asia that accept the pope as their head. The Eastern Catholic Churches also accept the doctrine and celebrate the sacraments of the Roman Catholic Church. However, unlike the Catholic Church in the West, the Eastern Catholic Churches allow married men to become priests. In addition, each of the Eastern Catholic Churches uses its own *liturgy* (acts of worship) and maintains its own structure, law, and customs.

The Eastern Catholic Churches include the Maronite Church in Lebanon, the Chaldean Church in Iran and Iraq, the Catholic Coptic Church in Egypt, and the Syro-Malabar Church in India. The Melkite, Ukrainian, Ruthenian, and Russian Catholic churches are Eastern Catholic Churches of the Byzantine Rite. About 12 million people belong to Eastern Catholic Churches.

The Eastern Catholic Churches are also referred to as Eastern Rite Churches because they have retained the liturgies that developed in the East Roman Empire. In addition, they are sometimes called Uniat or Uniate Churches because they broke from and later reunited with the Roman Catholic Church. Peter E. Fink

See also Copts.

Eastern Hemisphere. See Hemisphere.

Eastern Orthodox Churches are the major Christian churches in Greece, Russia, eastern Europe, and western Asia. As a federation of churches, they are united by common beliefs and traditions. Individually, they are usually called by their national names, such as the Greek Orthodox Church or the Russian Orthodox Church. About 170 million people belong to the Eastern Orthodox Churches.

Eastern Orthodox beliefs are based on the Bible and on *holy tradition* (doctrines worked out mostly during early centuries of Christianity). The decrees of church councils and the writings of early church leaders reflect the authority of church beliefs.

History. For the first 300 years following Jesus Christ, Christianity struggled for survival in the pagan Roman Empire. Today's distinction between the Eastern Orthodox and *Western* (Roman Catholic and Protestant) churches did not exist.

A turning point in church history came in 313 when Roman Emperor Constantine the Great granted Christians freedom to practice their religion. He called the First Nicene Council in 325. This was the first of seven ecumenical councils held between 325 and 787. The councils established church organization and doctrine (see **Nicene Councils**). In 330, Constantine moved his

capital from Rome to a new city which he named in his honor, Constantinople (now Istanbul, Turkey). The city became the center of eastern Christendom.

The year 1054 is generally considered the date of the *schism* (split) between the Eastern and Western churches. The two churches had been drifting apart for hundreds of years before the final schism. Many political, cultural, and geographical factors contributed to the final split. Two religious issues are generally considered the chief causes of the break. One issue concerned a phrase added to the Nicene-Constantinopolitan Creed called the *filioque*. Another issue was the Roman papal claims to authority over the entire church. Both issues led to a historic dispute in the 800's between Photius, patriarch of Constantinople, and Pope Nicholas I (see **Photius**). Disputes continued until, in 1054, delegates of Pope Leo IX issued an *anathema* (solemn curse of excommunication) against the patriarch of Constantinople. The patriarch then summoned a council that excommunicated the papal delegates.

In 1204, Western Christians on the Fourth Crusade increased the bitterness between Eastern and Western churches when they partially destroyed Constantinople. In 1453, the Ottoman Empire captured the city. The conquerors, who were Muslims, ruled most Orthodox Christians until the 1800's. Only in Russia, then under the rule of the czars, did the Orthodox church remain free of Muslim control. Under the Muslims, the patriarch of Constantinople was considered the senior bishop of all Orthodox believers. Muslim power declined in the 1800's, and several Orthodox churches gained self-government as subject peoples won their independence.

Ecumenical Patriarch Athenagoras I held a historic meeting with Pope Paul VI in 1964 in Jerusalem. The meeting was the first between a patriarch of Constantinople and a pope since 1439. In 1965, the two religious leaders lifted the mutual anathemas of 1054.

Organization. The Eastern Orthodox Churches consist of several independent and self-governing churches and some churches that are not completely self-governing. Four of the self-governing churches hold places of special honor for historical reasons. They are, in order of seniority, the churches of Constantinople (in Turkey), Alexandria (in Egypt), Antioch (Damascus, Syria), and Jerusalem. Other major self-governing churches, in order of rank, are the churches of Russia, Georgia, Serbia, Romania, Bulgaria, Cyprus, Greece, Albania, Poland, the Czech Republic and Slovakia, and America. Eastern Orthodox Churches give the greatest honor to the leader of the Church of Constantinople, called the *ecumenical patriarch*.

Eastern Orthodox Churches located in Canada, Finland and other western European countries, central Africa, Japan, and Sinai (Egypt), are not yet fully self-governing. They were established by missionaries and settlers from Orthodox Church countries and are supervised by a self-governing church. Nearly all people in Greece and Cyprus belong to an Eastern Orthodox church. The church cooperates closely with the government in these countries.

Clergy. There are three *major orders* of Orthodox clergy—bishops, priests, and deacons. There are also two chief *minor orders*—subdeacons and readers. The priesthood includes *married* and *monastic* clergy. Most married priests head parishes. Monastic clergy usually live in monasteries. Parochial clergy can marry only before ordination. Once ordained, priests and deacons cannot marry. Only unmarried priests can become bishops.

Deacons, subdeacons, and readers assist the priest during religious services. The spiritual life and administration are governed by the principle of shared responsibility between the clergy and *laity* (nonclergy). The laity often take part in the administration of their church and in the election of their clergy.

Doctrines. Eastern Orthodox Churches teach that their church is faithful to the teachings of the Apostles and free from errors in matters of doctrine. But they do not believe that any one person in the church is infallible. The Bible and holy tradition are the most important sources of Eastern Orthodox teachings. Daily church services are based on the Bible, especially on the Psalms. The services also include many hymns and prayers that reflect the Biblical teachings.

The Nicene-Constantinopolitan Creed expresses the beliefs of Eastern Orthodoxy. The creed probably dates from the First Council of Constantinople in A.D. 381. It is the only creed used in church services.

Eastern Orthodox Christians disagree with Roman Catholics and other Western Christians over the Nicene Creed and the doctrine of the Holy Trinity implied in the filioque addition. Orthodox Christians use the original text of the creed, which states that the Holy Spirit proceeds from the Father. They base their belief on a passage in the Gospel of Saint John (John 15: 26). Roman Catholics and other Western Christians use a later form of text, which states that the Holy Spirit proceeds from the Father *and from the Son*. This additional phrase is the filioque. The filioque and the papal claims to primacy and infallibility are the major doctrinal disagreements between the Eastern Orthodox Churches and the Roman Catholic Church.

Services in the Orthodox churches consist of the Divine Liturgy, the Divine Office, and Occasional Offices. The Divine Liturgy is the celebration of the *Eucharist*. The Divine Office consists of prayers and readings called Matins and Vespers and several lesser offices. Occasional Offices include services for baptisms, marriages, and funerals. All services are sung or chanted, usually in the language of the congregation.

The Eucharist is celebrated according to one of four rites. The two most common are the Liturgy of St. John Chrysostom and the Liturgy of St. Basil. The Eucharist is performed by the clergy and the congregation together. It recalls Christ's entire life. The celebration of the Eucharist includes processions and the taking of Holy Communion.

Church buildings. Orthodox churches are richly decorated with religious art. *Icons* (holy images) form an essential part of Orthodox worship. They stimulate the faith and piety of the worshipers. See **Icon**.

In each church an altar stands in the center of the sanctuary. A solid screen or partition, called an *iconostasis*, divides the sanctuary from the rest of the church. The congregation looks into the sanctuary through doorways in the iconostasis.

Sacraments. Eastern Orthodox Churches have seven major sacraments and several minor ones.

The Eucharist, a sacramental remembrance of the risen Christ and His victory over death, is a mystical sharing in the life and being of Christ by all believers. In the Eucharist, the faithful receive bread and wine that has been transformed into the body and blood of Christ by the Holy Spirit.

Baptism is a sacrament that admits infants and converts into the church. A priest immerses the body of the person who is being baptized into the water three times. He says, "The servant of God is baptized in the name of the Father and of the Son and of the Holy Ghost."

Chrismation (or Confirmation) is administered immediately after baptism. It grants the newly baptized person full membership in the church and the right to participate in the Eucharist.

Confession (or Penance) is a sacrament in which a person confesses sins to God in the presence of a priest. The priest forgives the sins in the name of God and offers the person spiritual advice.

Marriage joins man and wife and forms a family. Eastern Orthodox Churches permit divorce and allow divorced people to remarry. But the Eastern Orthodox Churches believe the first marriage is the greatest in the eyes of God. Most Orthodox churches permit only three marriages. When a divorced person remarries, several of the joyful ceremonies of the original marriage sacrament are replaced by prayers asking forgiveness.

Holy orders admits men to the major and minor orders of the clergy. Only a bishop can ordain. The congregation gives its consent to those taking holy orders by saying *axios (he is worthy)* during the service.

Anointing of the sick is a sacrament in which a priest anoints a sick person and prays for forgiveness of the person's sins and for his or her recovery. Critically reviewed by the Greek Orthodox Archdiocese of North and South America

Related articles in *World Book* include:

Byzantine art
Byzantine Empire
Eastern Catholic Churches
Greece (Religion)
Greek Orthodox Archdiocese of North and South America
Iconoclast
Liturgy
Patriarch
Religious life (The Eastern Orthodox Churches)
Russia (Religion)

Eastern Rite Churches. See Eastern Catholic Churches.

Eastern Star is an organization for women and men associated with the men's fraternal society of Masons. Its official name is the Order of the Eastern Star. Eastern Star has about 3 million members worldwide. They belong to several separate groups, including the General Grand Chapter, the Independent Grand Chapter of New York and New Jersey, and the Supreme Grand Chapter of Scotland. All Eastern Star groups support charitable projects and sponsor social activities for their members.

The General Grand Chapter is by far the largest Eastern Star group, with about $2\frac{1}{2}$ million members. Its members are chiefly wives, daughters, mothers, widows, sisters, half sisters, granddaughters, stepmothers, stepdaughters, and stepsisters of Masons who have earned at least the degree of Master Mason. Master Masons and Masons of higher degrees also may become members of the General Grand Chapter. The General Grand Chapter consists of 56 grand chapters in the United States and Canada, plus 90 chapters in other nations. All its chapters raise funds for such causes as arthritis, cancer, and heart disease research. The executive officer of the General Grand Chapter is a woman whose title is Most Worthy Grand Matron. Headquarters of Eastern Star are in Washington, D.C.

Critically reviewed by the Order of the Eastern Star

See also Masonry.

Eastman, George (1854-1932), was an American businessman and inventor. He made photography accessible to amateurs by introducing the low-cost, easy-to-operate Kodak camera and the roll of film.

Eastman was born on July 12, 1854, in Waterville, New York. His family moved to Rochester, New York, in 1860. There, he developed a dry photographic plate, which he began manufacturing in 1880. In 1888, Eastman introduced the Kodak. This lightweight, box-shaped camera contained film wound on rollers, eliminating the need for glass photographic plates. By the early 1900's, the Eastman Kodak Company had become the largest photographic film and camera producer in the world. Research and technical improvements helped keep Eastman ahead of his competitors. Reese V. Jenkins

See also **Photography** (The beginnings of modern photography; picture: The Kodak camera).

Eastman Kodak Company is one of the world's largest manufacturers of photographic equipment. It develops, manufactures, and markets photographic and chemical products for both amateur and professional photographers. The company's other products include X-ray films, pharmaceuticals, copier-duplicators, acetate fibers, polyethylene, polypropylene, polyester, and video cassettes.

The American businessman George Eastman founded the company in 1880 as a result of his interest in making amateur picture-taking easier and less expensive. Eastman revolutionized photography in 1885 when he introduced roll film, which used a paper base instead of glass. The company marketed its first camera in 1888, and in 1889 it introduced the first flexible, transparent roll film for commercial purposes. The company's headquarters are in Rochester, New York.

Critically reviewed by Eastman Kodak Company

Eastman School of Music, a division of the University of Rochester, is one of the most noted comprehensive music schools in the United States. Its resources include professional recording studios; practice and rehearsal rooms; five auditoriums; and the nation's largest college music library, the Sibley Library.

The school was founded in 1921. The American camera manufacturer George Eastman provided the new building for the school. Later, he established an endowment and gave funds for additional facilities.

Critically reviewed by the Eastman School of Music

Eastwood, Clint (1930-), is an American motion-picture actor and director. He is best known for his roles in violent action films, especially Westerns and urban police dramas. Eastwood usually plays tough, alienated loners. Many of his films take a pessimistic view of human nature, emphasizing greed, cruelty, and violence. His films often include one strong female character who helps the hero to some kind of redemption. Eastwood's movies often use black comedy.

Eastwood first attracted international fame for his performance as a gunman in three European-made Westerns that were directed by Sergio Leone of Italy. They

were *A Fistful of Dollars* (1964), *For a Few Dollars More* (1965), and *The Good, the Bad, and the Ugly* (1966). Eastwood's other important films as an actor include *Coogan's Bluff* (1968), *Dirty Harry* (1971), *Escape from Alcatraz* (1979), and *In the Line of Fire* (1993).

Eastwood was born in San Francisco. He made his film debut in *Revenge of the Creature* (1955). He made his debut as a director with *Play Misty for Me* (1971). He also directed and starred in *The Outlaw Josey Wales* (1976), *Sudden Impact* (1983), *Unforgiven* (1992), *The Bridges of Madison County* (1995), *Absolute Power* (1997), and *Space Cowboys* (2000). Eastwood received an Academy Award as best director for *Unforgiven,* which also won an Academy Award as best picture. He directed, but did not appear in, *Bird* (1988) and *Midnight in the Garden of Good and Evil* (1997). Louis Giannetti

Eaton, Peggy. See O'Neale, Peggy.

Eaton, Theophilus (1590-1658), a Puritan founder of New Haven colony, sailed from England for Boston in 1637 with 250 colonists. The group was invited to settle in Massachusetts, but the controversy over Anne Hutchinson was raging there, and news from England suggested that the colony might lose its charter (see **Hutchinson, Anne M.**). Most important, Eaton, a wealthy merchant, wanted a good harbor for trade.

Eaton and his friends left Boston, and in 1638 settled New Haven. They purchased land from the Indians and organized a church and court. Eaton was elected governor in 1639 and ruled almost as a dictator until his death. He helped found the New England Confederation (see **New England Confederation**). Eaton was born in Stony Stratford, England. John W. Ifkovic

Eaton, Timothy (1834-1907), was a noted Canadian merchant. He established Canada's first large department store chain and first mail-order business. Eaton revolutionized retail selling by offering goods for cash only and at a fixed price. Previously, merchants and customers had bargained about the prices of products or had simply exchanged one item for another.

Eaton was born near what is now Ballymena, Northern Ireland. He settled in Canada about 1854. In 1869, Eaton bought a store in Toronto and named it T. Eaton & Company (later Eaton's of Canada Limited). He began his mail-order business in 1884. Unlike many merchants of his time, Eaton opposed false or misleading advertisements and the use of extended-credit plans. He sold only high-quality products and introduced the money-back guarantee for dissatisfied customers. Eaton's policies helped his company become one of the world's largest family-owned businesses. Sears Canada, Inc., bought the company in 1999 and dropped the Eaton name in 2002.
Alan Wilson

Eberhart, Richard (1904-), is an American poet. His *Selected Poems (1930-1965)* won a 1966 Pulitzer Prize. Eberhart won the 1977 National Book Award for *Collected Poems, 1930-1976.* Meditating on birth, war, disease, and death, he writes poems that are, to use a phrase from one of them, "true originals of imagination." As he confronts these major mysteries of human experience, the force of his feeling erupts into a series of surprise effects in his poems. These effects include mixtures of abstraction and outcry, rough meters, inverted word orders, and sudden strikingly brilliant and lyrical lines.

Eberhart was born on April 5, 1904, in Austin, Minnesota. He published his *Collected Verse Plays* in 1962. His prose was collected in *Of Poetry and Poets* (1979). Eberhart's *Collected Poems, 1930-1986* was published in 1988. Bonnie Costello

Ebla was a kingdom that flourished during the 2000's B.C. in what is now northern Syria. The exact dates of its founding and destruction are not known, but archaeologists believe Ebla existed sometime between 2700 and 2200 B.C. Ebla, a wealthy and powerful city-state with a highly advanced civilization, had about 260,000 people.

Ebla's economy was based on the manufacture of metal products and textiles. The kingdom gained great wealth through trade agreements with neighboring states. Ebla also received large payments called *tributes* from less powerful city-states.

The people of Ebla were Semites. They spoke a Semitic language that resembled ancient Hebrew. Ebla was ruled by a king, who controlled a government that had about 11,000 civil servants. Eblaite scribes recorded information on clay tablets about the kingdom's business, government, and religion. The clay tablets were inscribed in *cuneiform,* an ancient system of writing developed by the Sumerian people of Mesopotamia.

Archaeologists found the ruins of the royal palace at Ebla in 1974. In 1975, they found about 15,000 clay tablets with information about Ebla's law, religion, and economic and political development. David Noel Freedman

Ebola virus, *eh BOH luh,* is a virus that has led to several outbreaks of deadly disease in Africa. It is named for the Ebola River in northern Congo (Kinshasa). The first known outbreaks occurred in this region and in western Sudan in 1976, killing hundreds of people. Outbreaks also occurred in Sudan in 1979, in western Zaire (now called Congo [Kinshasa]) in 1995, and in Uganda in 2000.

In human beings and monkeys, the virus causes Ebola hemorrhagic fever, an illness characterized by fever, headache, diarrhea, vomiting, and massive internal bleeding. Most other hemorrhagic viruses have a *host,* often a rodent or insect, which carries the virus but does not become ill. Scientists have not yet identified the host for Ebola virus. The virus is spread by contact with the blood or other bodily fluids of an infected person, body tissue, or unsterilized needles or other equipment. Symptoms appear within 5 to 10 days of infection. About 80 to 90 percent of all people who become infected die.

There is no known cure or vaccine for Ebola virus. Prevention efforts involve educating people about how the virus is transmitted and isolating infected individuals. Jennifer A. Rupp

Ebony, *EHB uh nee,* is a hard, black wood. This wood can be polished to an almost metallic luster. Ebony trees grow in Australia, Asia, Africa, and tropical regions of North and South America.

Only the *heartwood* (inner wood) is dark-colored. The *sapwood* (outer wood) is lighter-colored. In some species, the heartwood also is light-colored. A hard gum in the heartwood is probably responsible for ebony's brittleness, which makes it easy to carve.

Ebony is used mainly for black piano keys, flutes, handles of knives and brushes, wood inlays on furniture, and other ornamental objects. The persimmon trees of the United States and Asia are species of ebony. But these trees have little commercial value. Alwyn H. Gentry

Scientific classification. Ebony trees belong to the ebony

family, Ebenaceae. The ebony tree of India and Sri Lanka is *Diospyros ebenum.* The common persimmon is *D. virginiana.*

See also **Persimmon.**

Ecclesiastes, *ih KLEE zee AS teez,* is the 21st book of the Old Testament, or Hebrew Bible. The meaning of its name in Hebrew, *Qohelet,* is unclear. It may be related to a Hebrew word for *assembly,* which was translated into *Ekklesiastes,* or *assembly man,* in Greek. In some English Bibles, the title is translated as *Preacher.*

The book is a collection of proverbs set within the narrator's life story. Many of its ideas are unique in Biblical thought. For example, Ecclesiastes expresses pessimism about the value of human existence. The narrator is troubled by injustice in the world and that the meaning of life is hidden from people. The book urges people to enjoy life's pleasures. But one should not make pleasure the goal of living because, in the end, life is empty, or the "vanity of vanities." Ecclesiastes ends with a moving chapter about the narrator's approaching death.

Ecclesiastes is one of the Bible's *wisdom books,* or books that give instruction for living. According to tradition, the author is Solomon, the Israelite king famous for his wisdom (see **Solomon**). However, the style and language indicate that the book was written in the 400's or 300's B.C., long after Solomon's reign. Carol L. Meyers

ECG. See **Electrocardiograph.**

Echidna, *ih KIHD nuh,* is a type of mammal that lays eggs. The platypus is the only other mammal that does not give birth to live young. Echidnas are also called *spiny anteaters.* They have coarse, brown hair and many sharp spines on their back and sides. They eat chiefly ants and termites. Echidnas live in a wide range of habitats in Australia and New Guinea. There are two species.

Echidnas measure over 12 inches (30 centimeters) long and weigh from 7 to 22 pounds (3.2 to 10 kilograms). Their nostrils and mouth are at the end of a long, thin snout. Echidnas have a long tongue and sticky saliva that they use to lick up insects. An echidna has no teeth. It crushes its food with horny plates at the base of the tongue and on the roof of the mouth. Echidnas have strong claws, which they sometimes use to dig burrows. An echidna also digs rapidly straight into the ground and partly buries itself for protection against enemies.

Female echidnas lay one egg a year. The egg has a tough, leathery shell and hatches in a pouch that forms on the female's belly each mating season. The young echidna remains in the pouch for several weeks and feeds on the mother's milk. Michael L. Augee

Scientific classification. Echidnas are in the family Tachyglossidae in the order Monotremata. The two species are *Tachyglossus aculeatus* and *Zaglossus bruijni.*

Echinacea, *EHK uh NAY shee uh* or *EHK uh NAY see uh,* is the name of several species of plants with colorful flowers on slender stems. The *narrow-leaved purple coneflower, pale purple coneflower,* and *common purple coneflower* are the most common kinds of echinacea. They develop pinkish white to purple flowers, and possess leaves that range from oval-shaped to lance-shaped. People have commonly used these three species in medicines.

Traditionally, Native Americans used echinacea roots and root extracts to treat such ailments as colds, headaches, snakebites, stomachaches, and toothaches. In modern times, researchers have observed that certain preparations of echinacea can help treat colds, influenza, and various infections. People also take echinacea extracts to help boost their immune systems. Such extracts increase the activity of *phagocytes* in the body. Phagocytes are white blood cells capable of destroying disease-producing bacteria and other harmful material.

Gardeners commonly plant echinacea as ornamental flowers. Due to overcollection, some wild species of the plant are in danger of disappearing. Lyle E. Craker

Scientific classification. Echinacea belong to the composite family, Compositae. The narrow-leaved purple coneflower is *Echinacea angustifolia.* The pale purple coneflower is *E. palida.* The common purple coneflower is *E. purpurea.*

Echinoderm, *ih KY nuh durm,* is the general name of certain spiny-skinned sea animals. There are about 6,000 kinds of echinoderms. Starfish, brittle stars, sand dollars, sea urchins, and sea cucumbers are among the most common kinds. All echinoderms have an internal bony skeleton. Their spines are a part of the skeleton. The echinoderm *phylum* (large animal group) is the only major phylum made up entirely of sea animals.

An adult echinoderm has *radial symmetry.* Its body parts are arranged around its center like the spokes of a wheel around the hub. Echinoderm bodies are usually divided into five sections, with the mouth in the center.

Echinoderms are the only animals that have many tiny tubelike structures called *tube feet.* The tube feet project from the body in rows. Echinoderms use the tube feet for moving, feeding, breathing, and sensing. The outer tip of each tube often forms a suction disk for gripping hard surfaces. Within the echinoderm's body, a tiny bulb attached to the tube foot forces water into it to make it lengthen. An internal system of water-filled canals connects the tube feet to each other and to a sievelike plate that usually opens to the sea water. The entire system of tube feet and canals is called the *water vascular system.*

Echinoderms reproduce by laying eggs that develop into larvae and swim freely. The larvae have *bilateral symmetry* (two similar halves). The larvae sink to the ocean bottom and change into the adult, radial form.

John C. Ferguson

Scientific classification. Echinoderms make up the echinoderm phylum, Echinodermata.

See also **Sand dollar; Sea cucumber; Sea lily; Sea urchin; Starfish; Brittle star.**

Echo is a sound heard when it is reflected back to its source after striking some object. When we shout or clap our hands, we produce sound waves that travel through the air in all directions. We first hear the sound when the waves reach our ears by the most direct path (see **Sound** [The nature of sound]). If the waves also hit a large object, such as the side of a building, they bounce back and may reach our ears a second time. The second sound is an echo. It is probably named for the nymph Echo in Greek mythology (see **Narcissus**).

Sometimes we do not hear echoes. We may not hear an echo if the original sound is too weak, if the object absorbs rather than reflects the sound, or if the reflecting object is too small. We may not be able to tell the difference between the direct sound and its echo if the reflecting object is less than about 30 feet (9 meters) away, because they arrive at nearly the same time.

At other times, we may hear more than one echo from just one original sound. Such repeated echoing

usually occurs in valleys and canyons where there are many sound-reflecting surfaces. The sound waves bounce from wall to wall and may often produce several echoes. Such repeated echoes are called *reverberation.*

Echoes can help us find out how far we are from echo-producing objects. Sound waves travel about 1 mile (1.6 kilometers) in 5 seconds. It takes 10 seconds for sound to reach an object a mile away and return. If a person who stands and shouts at the edge of a canyon hears the echo five seconds later, the canyon is about $\frac{1}{2}$ mile (0.8 kilometer) wide.

Sound waves traveling through water also produce echoes. A device called *sonar* uses underwater echoes to measure depth and to locate underwater objects. It is used in navigation to locate underwater channels, and can even detect schools of fish. Thomas A. Griffy

See also **Bat** (How bats navigate); **Radar** (Pulse radar; diagram); **Sonar.**

Echolocation. See **Bat** (How bats navigate); **Dolphin** (mammal); **Mammal** (Senses); **Whale** (Senses).

Eck, Johann (1486-1543), was a Catholic theologian who debated Martin Luther at Leipzig in 1519. He made Luther admit to holding some of the same opinions as did John Hus, a reformer who was executed in 1415 as a heretic. During the debate, Luther attacked the Council of Constance for condemning Hus. Eck claimed that to deny the authority of the council was heresy.

Eck, a brilliant, belligerent man, helped engineer Luther's excommunication in 1521 and fought Protestantism the rest of his life. Eck's writings vigorously defended the papacy, purgatory, oral confession, and other Catholic doctrines rejected by Luther and his followers. Eck also attacked Swiss reformer Huldreich Zwingli and the Reformation in Switzerland. Eck was born in Swabia, now in southwestern Germany, on Nov. 13, 1486. In 1510, he became a professor of theology at the University of Ingolstadt in southern Germany. M. U. Edwards

See also **Hus, John; Luther, Martin; Reformation.**

Eckert, J. Presper, Jr. (1919-1995), was a pioneer in the development of the modern electronic digital computer. He was the chief engineer on the project that built ENIAC (*E*lectronic *N*umerical *I*ntegrator *A*nd *C*omputer), one of the world's first general-purpose electronic digital computers. He also helped develop UNIVAC (*UNI*-*V*ersal *A*utomatic *C*omputer), the first computer to achieve commercial success.

John Presper Eckert, Jr., was born on April 9, 1919, in Philadelphia. He graduated from the Moore School of Electrical Engineering at the University of Pennsylvania in 1941.

During World War II (1939-1945), the United States Department of War desperately needed to calculate quickly the firing tables used by gunners to aim artillery. In 1943, the department accepted a proposal to build an electronic computer for this purpose. The proposal's authors were Eckert, then a graduate student at the University of Pennsylvania, and engineering professor John Mauchly. Eckert, Mauchly, and their team completed the machine, ENIAC, in late 1945 and first demonstrated it publicly in 1946. Later in 1946, Eckert and Mauchly founded the Electronic Control Company (later renamed the Eckert-Mauchly Computer Corporation). Remington Rand, Inc. (now part of Unisys Corporation), bought the company in 1950. Eckert and Mauchly completed UNIVAC while working at Remington Rand. Paul N. Edwards

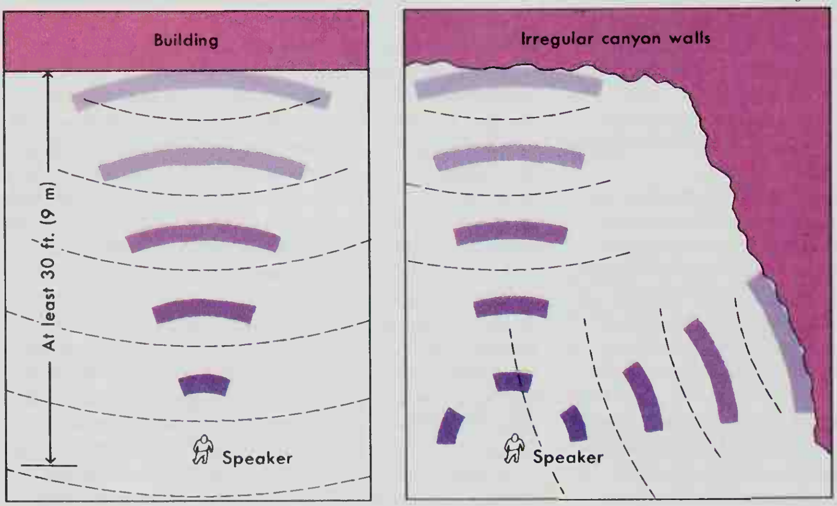
See also **Computer** (The first electronic computers; picture; ENIAC); **Mauchly, John William.**

Eckhart, Johannes (1260?-1328), was a German theologian. He is usually called *Meister* (Master) *Eckhart.* Eckhart was an influential preacher, and his sermons helped shape Christian mysticism in the late Middle Ages (see **Mysticism**). His sermons also played a role in the development of German as a literary language.

Eckhart taught that the goal of a Christian was union with God. A person achieved this union through total detachment from worldly matters. Eckhart believed every person's soul contained a divine spark. Through this spark, the soul might unite with God. To create the state of mind required for the mystical union with God, a person had to withdraw from sin. The person also had to conquer time and human nature.

Eckhart was born in Hochheim, near Erfurt, and studied in Erfurt and at the University of Paris. He entered the Dominican Order as a young man and held several

WORLD BOOK diagrams



Echoes can be produced by shouting at a large object located at least 30 feet (9 meters) away. The drawing at the left shows sound waves from a person's voice hitting the side of a large building and bouncing back in the form of echoes. Sound waves reaching surfaces at different distances return to the speaker at different times, as shown by the drawing at the right.

positions of authority in the order. Eckhart taught in Cologne, Germany, from 1320 to 1326, when the church questioned the orthodoxy of some of his ideas. He admitted he might be in error but refused to acknowledge that he taught *heresy* (false doctrine). He died while awaiting the pope's decision on his case. In 1329, Pope John XXII condemned as heresy 28 ideas from Eckhart's writings. William J. Courtenay

Eclampsia. See Preeclampsia.

Eclipse is the darkening of a heavenly body. It occurs when the shadow of one object in space falls on another object or when one object moves in front of another to block its light. A *solar eclipse* takes place when the sun appears to become dark as the moon passes between the sun and the earth. A *lunar eclipse* occurs when the moon darkens as it passes through the earth's shadow.

Heavenly bodies other than the earth and the moon also can eclipse each other. The planet Jupiter sometimes blocks sunlight from its moons. Likewise, Jupiter's moons sometimes cast shadows on the planet. Sometimes the moon or some other heavenly body blocks light from a planet or a distant star. Astronomers use the term *occultation* for this blocking action. Astronomers also refer to a certain kind of *variable star* as an *eclipsing binary* (see **Star** [Binary stars]). An eclipsing binary consists of two stars that revolve around each other so that each periodically blocks the light from the other. This article discusses chiefly lunar and solar eclipses.

When eclipses occur. The earth and the moon always cast shadows into space, and the moon orbits the earth about once every month. But an eclipse—either solar or lunar—does not occur every month. The moon's orbit is tilted about 5° to the earth's orbit around the sun. For this reason, the moon's shadow generally misses the earth, and so a solar eclipse does not occur. Likewise, the moon most often escapes being eclipsed by passing above or below the shadow of the earth. Thus, a solar or a lunar eclipse can occur only when the earth, sun, and moon are in nearly a straight line.

Astronomers can predict eclipses with great accuracy. At least two solar eclipses and as many as three lunar eclipses may be seen each year from various places on the earth.

Solar eclipses occur when the moon's shadow sweeps across the face of the earth. The shadow usually moves from west to east across the earth at a speed of about 2,000 miles (3,200 kilometers) per hour. People in the path of the shadow may see one of three kinds of eclipses. A *total eclipse* occurs if the moon completely blots out the sun. If the moon is at its farthest point from the earth when a total eclipse occurs, the eclipse may be only an *annular eclipse*. In such an eclipse, the moon darkens only the middle of the sun, leaving a bright ring around the edges. A *partial eclipse* occurs if the moon covers only part of the sun.

A total solar eclipse is one of nature's most impressive sights. The dark moon appears on the western edge of the sun and moves slowly across the sun. At the moment of total eclipse, a brilliant halo flashes into view around the darkened sun. This halo is the sun's outer atmosphere, the *corona*. The sky remains blue but darkens. Some bright stars and planets may become visible from the earth. After a few minutes, the sun reappears as the moon moves off to the east. The period when the sun is totally darkened may be as long as 7 minutes 40 seconds, but it averages about $2\frac{1}{2}$ minutes.

A total solar eclipse can be seen only in certain parts of the world. These areas lie in the *path of totality*, the path along which the moon's shadow passes across the earth. The path of totality is never wider than about 170 miles (274 kilometers).

A partial solar eclipse or a partial phase of a total eclipse should be viewed only with special filters that cut the solar light to a safe level. Sunglasses and smoked glasses do not provide enough protection.

You can also view the sun indirectly with a *pinhole projector*—two pieces of cardboard, one with a small hole punched through it. Hold this piece so that sunlight passes through the hole and casts an image on the other piece. Spaces between tree leaves can also serve as pinholes, casting images on the ground.

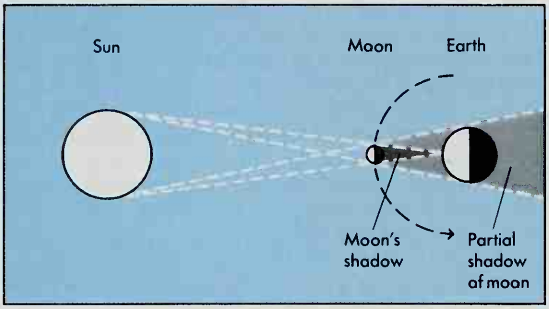
A total solar eclipse can be viewed safely without protection only when the disk of the sun is completely hidden and only the corona is visible. The corona is no brighter than a full moon.

Lunar eclipses take place when the moon passes through the shadow of the earth. A *total eclipse* occurs if the entire moon passes through the earth's shadow. A *partial eclipse* occurs if only part of the moon passes through the shadow. A total lunar eclipse may last up to 1 hour 40 minutes. A lunar eclipse may be seen by most of the people on the night side of the earth. There is no danger in viewing a lunar eclipse.

The moon does not become completely dark during most lunar eclipses. In many cases, it becomes reddish. The earth's atmosphere bends part of the sun's light

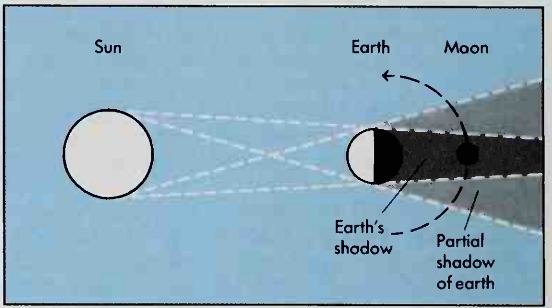
Maurice E. Snook

A total eclipse of the sun, as shown here, starts at the left. The moon gradually covers the sun, shown photographed through a filter. At the time of total eclipse, photographed without a filter, the sun's *corona* (outer atmosphere) flashes into view. The sun reappears as the moon moves on.



WORLD BOOK diagram

A solar eclipse occurs when the moon passes between the sun and the earth. In areas on the earth that lie in the moon's shadow, the sun cannot be seen at all or is visible as only a bright ring. In areas in the partial shadow of the moon, only a portion of the moon blocks the sun.



WORLD BOOK diagram

A lunar eclipse takes place when the earth is directly between the sun and the moon. The moon gradually becomes darker as it moves into the shadow of the earth, but it does not become completely dark. With the sun, earth, and moon positioned as shown, the moon is totally eclipsed.

around the earth and toward the moon. This light is red because the atmosphere scatters the other colors present in sunlight in greater amounts than it does red.

The study of eclipses. Eclipses have fascinated people for thousands of years. The ancient Chinese thought solar eclipses occurred when a dragon in the sky tried to swallow the sun. Modern astronomers have learned much by studying eclipses. They have observed solar eclipses to determine the exact relative positions of the earth, sun, and moon. In 1939, astronomers observed that the moon's surface cooled extremely rapidly during a lunar eclipse. For this reason, they theorized that the moon is covered by a layer of fine dust. This theory was proved correct by space probes on the moon in the 1960's. Astronomers have also observed eclipses to study possible changes in the strength of gravity and the size of the sun.

Total solar eclipses, 1985-2015

Date	Path of total eclipse
Nov. 12, 1985	South Pacific Ocean
March 18, 1988	Indonesia, Philippines, Pacific Ocean
July 22, 1990	Northern Siberia, Aleutian Islands
July 11, 1991	Hawaii, Mexico, Central America, Colombia, Brazil
June 30, 1992	South Atlantic Ocean
Nov. 3, 1994	South America, South Atlantic Ocean
Oct. 24, 1995	Southern and southeast Asia, Indonesia
March 9, 1997	Mongolia, eastern Siberia
Feb. 26, 1998	Pacific Ocean, Central America, Colombia, Venezuela, Caribbean Sea
Aug. 11, 1999	North Atlantic Ocean, Europe, Middle East, southern Asia
June 21, 2001	Atlantic Ocean, central Africa
Dec. 4, 2002	Antarctica, south Indian Ocean
Nov. 23, 2003	Antarctica, south Indian Ocean, Australia
March 29, 2006	West Africa, southwestern Europe
Aug. 1, 2008	Siberia
July 22, 2009	Western Pacific Ocean
July 11, 2010	Central Pacific Ocean
Nov. 13, 2012	South Pacific Ocean
March 20, 2015	Scandinavia, northern Siberia, Arctic Ocean

Measurements of the sun's corona and certain kinds of other studies can be made best during a total solar eclipse. The famous physicist Albert Einstein claimed in his theory of general relativity that light from stars beyond the sun bends slightly from a straight path as it passes the sun. Normally, the bright glare of the sun drowns out starlight passing near the sun. But this light can be photographed during a total solar eclipse. Photographs taken during an eclipse in 1919 strongly supported Einstein's theory.

Astronomers study eclipses by heavenly bodies other than the earth and moon. They have determined the size of distant stars by observing eclipsing binaries.

In 1675, Danish astronomer Olaus Roemer used observations of eclipses of Jupiter's moons to show that light travels at a *finite* (limited) speed and to measure this speed. Jupiter eclipses its moons when the moons pass behind that planet as seen from the earth. Roemer noted that the time at which an eclipse becomes visible depends on how close the earth is to Jupiter. The eclipse becomes visible later when the earth is relatively far from Jupiter than it does when the earth is relatively close to Jupiter. However, the actual eclipse is not "late." The light merely takes more time to reach the earth. Roemer's measurement was within 25 percent of the actual speed of light. Lee J. Rickard

See also **Baily's beads**.

Ecofact. See **Archaeology** (What archaeologists study; picture).

École des Beaux-Arts, *ay KAWL day boh ZAHR,* is a school of fine arts in Paris sponsored by the French government. It dates from a school founded by Jules Cardinal Mazarin in 1648. The École des Beaux-Arts became famous during the 1800's and early 1900's for its architectural teaching. It promoted the design of buildings according to ancient Greek and Roman architectural models. It influenced the teaching of architecture and the design of civic buildings in many countries, including the United States.

Today, the École des Beaux-Arts offers courses in drawing, engraving, lithography, mosaic, mural art, and painting. The school is known for placing a strong emphasis on traditional design. The full name of the École des Beaux-Arts is École Nationale Supérieure des Beaux-Arts. P. A. McGinley

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Ecology is the study of living things and how they interact with one another and with the nonliving elements of their environment. Ecologists study these relationships wherever life is found—from the savannas of Africa, *above left*, to the coral reefs of the tropical oceans, *above right*.

Ecology

Ecology, *EE KAHL uh jee,* is the branch of science that deals with the relationships living things have to each other and to their environment. Scientists who study these relationships are called *ecologists.*

The world includes a tremendous variety of living things, from complex plants and animals to simpler organisms, such as fungi, amebas, and bacteria. But whether large or small, simple or complex, no organism lives alone. Each depends in some way upon other living and nonliving things in its surroundings. For example, a moose must have certain plants for food. If the plants in its environment were destroyed, the moose would have to move to another area or starve to death. In turn, plants depend upon such animals as moose for the *nutrients* (nourishing substances) they need to live. Animal wastes and the decay of dead animals and plants provide many of the nutrients plants need.

The study of ecology is important because our survival and well-being depend on ecological relationships around the world. Even changes in distant parts of the world and its atmosphere affect us and our own environment.

Although ecology usually is considered a branch of biology, ecologists must employ such disciplines as chemistry, physics, and computer science. They also rely on such fields as geology, meteorology, and oceanography to study air, land, and water environments and their interactions. This *multidisciplinary* approach helps ecologists understand how physical environments affect living things. It also helps them assess the impact of environmental problems, such as acid rain or the greenhouse effect (see **Acid rain; Greenhouse effect**).

Ecologists study the organization of the natural world on three main levels: (1) populations, (2) communities, and (3) ecosystems. They analyze the structures, activities, and changes that take place within and among these levels. Ecologists normally work out of doors, studying the operations of the natural world. They often conduct field work in isolated areas, such as islands, where the relationships among the plants and animals may be simpler and easier to understand. For example, the ecology of Isle Royale, an island in Lake Superior, has been studied extensively. Many ecological studies focus on solving practical problems. For example, ecologists search for ways to curb the harmful effects of air and water pollution on living things.

Populations

A population is a group of the same species that lives in an area at the same time. For example, all the moose on Isle Royale make up a population, as do all the spruce trees. Ecologists determine and analyze the number and growth of populations and the relationships between each species and the environmental conditions.

Factors that control populations. The size of any population depends upon the interaction of two basic forces. One is the rate at which the population would grow under ideal conditions. The second is the combined effect of all the less-than-ideal environmental factors that limit growth. Such limiting factors may include low food supply, predators, competition with organisms of the same or different species, climate, and disease.

The largest size of a particular population that can be supported by a particular environment has been called the environment's *carrying capacity* for that species. Real populations normally are much smaller than their environment's carrying capacity for them because of the effects of adverse weather, a poor breeding season, hunting by predators, or other factors.

Factors that change populations. Population levels of a species can change considerably over time. Some-

times these changes result from natural events. For example, a change in rainfall may cause some populations to increase and others to decrease. Or the introduction of a new disease can severely decrease the population of a plant or animal species. In other cases, changes may result from human activities. For example, power plants and automobiles release acidic gases into the atmosphere, where they may mix with clouds and fall to earth as acid rain. In some regions that receive large amounts of acid rain, fish populations have declined dramatically.

Communities

A community is a group of animal and plant populations living together in the same environment. Wolves, moose, beavers, and spruce and birch trees are some of the populations that make up the forest community of Isle Royale. Ecologists study the roles different species play in their communities. They also study the different types of communities, and how they change. Some communities, such as an isolated forest or meadow, can be identified easily. Others are more difficult to define.

A community of plants and animals that covers a large geographical area is called a *biome*. The boundaries of different biomes are determined mainly by climate. The major biomes include deserts, forests, grasslands, tundra, and several types of aquatic biomes. See **Biome**.

The role of a species in its community is called its *ecological niche*. A niche consists of all the ways that a species interacts with its environment. It includes such factors as what the species eats or uses for energy; what predators it has; the amounts of heat, light, or moisture it needs; and the conditions under which it reproduces. Ecologists have long noted that many species occupy a highly specialized niche in a given community. Various explanations have been proposed for this. Some ecologists feel that it results from competition—that if two species try to "fill" the same "niche," then competition for limited resources will force one of the species out. Other ecologists maintain that a species that occupies a highly specialized niche does so because of the rigid physiological demands of that particular role in the community. In other words, only one species occupies the niche not because it has out-competed other species, but because it is the only member of the community physiologically capable of playing that role.

Changes in communities occur over time in a process called *ecological succession*. This process occurs as a series of slow, generally predictable changes in the number and kinds of organisms in an area take place. Differences in the intensity of sunlight, protection from wind, and changes in the soil may alter the kinds of organisms that live in an area. These changes may also alter the number of populations that make up the community. Then, as the number and kinds of species change, the physical and chemical characteristics of the area undergo further changes. The area may reach a relatively stable condition called the *climax community*, which may last hundreds or even thousands of years.

Ecologists distinguish two types of succession—primary and secondary. In *primary succession*, organisms begin to inhabit an area that had no life, such as a new island formed by a volcanic eruption. *Secondary succession* takes place after an existing community suffers a major disruption—for example, after a climax forest community is destroyed by fire. In this example, a meadow community of wildflowers and grasses will grow first, followed by a community of shrubs. Finally trees will reappear, and the area will eventually become a forest once more, until it is disturbed again. Thus the forces of nature ultimately cause even climax communities to change. Increasingly, ecologists view fires and other large natural disturbances as acceptable and even desirable. See **Forest** (Forest succession).

Ecosystems

An ecosystem is the most complex level of organization in nature. It is made up of a community and its *abiotic* (nonliving or physical) environment, including climate, soil, water, air, nutrients, and energy. Ecologists who try to link together the many different physical and biological activities in an environment are called *systems ecologists*. Their studies often focus on the flow of energy and the cycling of materials through an ecosystem. They generally use powerful computers to help understand the data obtained from field research and to predict future developments.

Energy flow. Ecologists categorize the elements that make up or affect an ecosystem into six main parts, based on the flow of energy and nutrients through the system: (1) the sun, (2) abiotic substances, (3) primary producers, (4) primary consumers, (5) secondary consumers, and (6) decomposers. A simplified ecosystem is illustrated in this article.

The sun provides the energy that nearly all *primary producers* need to make food. Primary producers consist mainly of green plants, such as grass and trees, which make food by the process of photosynthesis (see **Photosynthesis**). Plants also need *abiotic substances*, such as phosphorus and water, to grow. *Primary consumers* include mice, rabbits, grasshoppers, and other plant-eating animals. Foxes, skunks, and other *secondary consumers*—or predators—eat animals. *Decomposers*, such as bacteria and fungi, break down dead plants and animals into simple nutrients. The nutrients go back into the soil and are used again by plants.

The series of stages energy goes through in the form of food is called a *food chain*. In one simple food chain, grass is the primary producer. A primary consumer, such as a rabbit, eats the grass. The rabbit, in turn, may be eaten by a secondary consumer, such as a fox or a hawk. Decomposing bacteria break down the uneaten remains of dead grass, rabbits, foxes, and hawks, as well as animal body wastes. One of the food chains on Isle Royale has trees as primary producers, moose as primary consumers, and wolves as secondary consumers.

Most ecosystems have a variety of producers, consumers, and decomposers, which form an overlapping network of food chains called a *food web*. Food webs seem especially complex in many tropical and oceanic ecosystems.

Some species eat many things, but others have very specific food requirements. Such primary consumers as koalas and pandas eat chiefly one type of plant. Koalas eat primarily eucalyptus and pandas eat primarily bamboo. If these plants died off, so would the animals.

Energy moves through an ecosystem in a series of transformations. First, primary producers change the light energy of the sun into chemical energy that is

stored in plant *protoplasm* (cell material). Next, primary consumers eat the plants, changing the energy to a different kind of chemical energy that is stored in body cells. This energy changes again when the secondary consumer eats the primary consumer.

Most organisms have a low *ecological efficiency.* This means they are able to convert only a small fraction of the energy available to them into stored chemical energy. For example, green plants can change only about 0.1 to 1 percent of the solar energy that reaches them into plant protoplasm. Most of the energy captured by the plants is burned up during plant growth and escapes into the environment as heat. Similarly, *herbivores* (plant-eating animals) and *carnivores* (meat-eating animals) convert into their own body cells only about 10 to 20 percent of the energy produced by their food.

Because so much energy escapes as heat at each step of the food chain, all ecosystems develop a *pyramid of energy.* Plants (primary producers) form the base of this pyramid. Herbivores (primary consumers) make up the next step, and carnivores (secondary consumers) form the top. The pyramid reflects the fact that more energy passes through the plants than through the herbivores, and more through the herbivores than through the carnivores. In many land ecosystems, the pyramid of energy results in a *pyramid of biomass.* This means that the total *biomass* (weight) of the plants is greater than the total weight of the herbivores, which in turn exceeds the total weight of the carnivores. In the oceans, however, the biomass of plants and animals is about the same. Small plants grow so rapidly in the oceans that they can support proportionately more animals than can the plants on land.

Ecologists have collected information on a pyramid of biomass on Isle Royale. They studied the relationship in the pyramid among plants, moose, and wolves. In one study, ecologists found that it takes 762 pounds (346 kilograms) of plant food to support 59 pounds (27 kilograms) of moose. This is the amount of moose needed to support 1 pound (0.45 kilogram) of wolf.

Cycling of materials. All living things are composed of certain chemical elements and compounds. Chief among these are water, carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur. All of these materials cycle through ecosystems again and again.

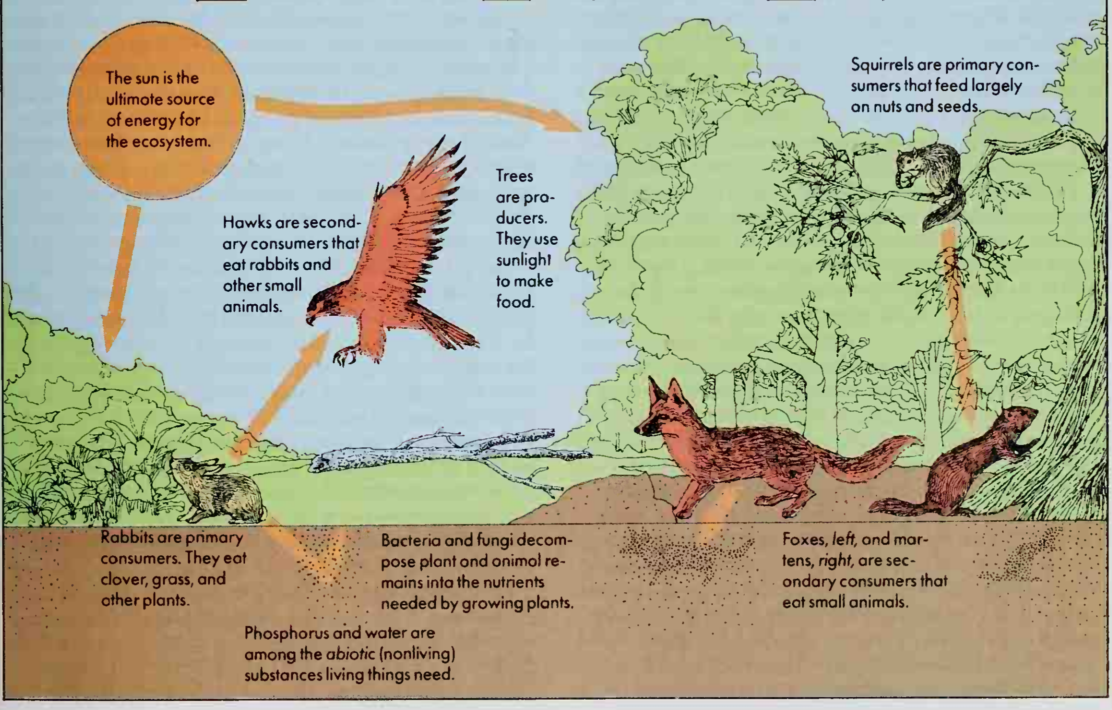
The cycling of phosphorus provides an example of this process. All organisms require phosphorus. Plants take up phosphorus compounds from the soil, and animals get phosphorus from the plants or other animals they eat. Decomposers return phosphorus to the soil after plants and animals die.

In natural, undisturbed ecosystems, the amount of phosphorus remains fairly constant. But when an ecosystem is disturbed, especially by human activity, the

WORLD BOOK diagram by George Suyeoka

An ecosystem This diagram shows a highly simplified ecosystem. *Ecosystem* is a scientific term for all the living and nonliving things in a given area and the relationships among them. In any ecosystem, the most important relationships involve the movement of food and energy through the system, starting with the sun and involving the other main parts of the ecosystem. In the diagram, each of the six main parts of the ecosystem is color-coded as indicated by the key, *below.*

Solar energy | Producers | Secondary consumers
Abiotic substances | Primary consumers | Decomposers



phosphorus often "leaks out." This reduces the ability of the ecosystem to support plants. One way people alter the phosphorus cycle is by replacing forests with farmland. Without the protection of the forests, phosphorus is eroded with the soil and swept away into rivers and lakes. There, it often causes undesirable excess growth of algae. Eventually, the phosphorus becomes locked in sediments at the bottom of lakes or the sea. Because of this loss of phosphorus, farmers must use costly fertilizers to put the element back into the soil.

Changes in ecosystems occur daily, seasonally, and, as in the case of ecological succession, over periods of many years. Sometimes changes take place severely and abruptly, as when a fire sweeps through a forest or a hurricane batters a seashore. But most of the day-to-day changes, especially in the nutrient cycles, are so subtle that ecosystems tend to appear stable. This apparent stability among plants and animals and their environment has been called the "balance of nature." In the past, this concept of balanced, largely unchanging ecosystems was thought to be especially descriptive of climax communities. But these earlier views were based on short-term studies. Now that ecologists have had an opportunity to study ecosystems over longer periods, they have had to alter some of their ideas.

Conclusions based on population studies from Isle Royale point out some of this change in thinking. For a long time, Isle Royale had neither moose nor wolf. Then, the first moose swam to the island in about 1900. By 1930, ecologists estimated that the moose population had reached about 3,000. There was evidence that the moose were eating many of the plants on the island. In 1933, the moose began to die of starvation. Ecologists had predicted this decline because they understood the food relationship between the moose and plants.

The moose population increased again between 1948 and 1950. However, about this time, wolves made their way to the island. As they killed moose for food, the wolf population grew. Eventually, an apparently stable balance of about 600 moose and 20 wolves became established. Ecologists pointed to Isle Royale as an example of the way in which predators can control prey and thus contribute to the development of stability in ecosystems.

But beginning in the mid-1960's, the moose and wolf populations began to fluctuate. The apparently stable system, in which predators controlled their prey, turned out to be more complex. During the 1950's, when it looked as if wolves were controlling the moose, the winters were characterized by an unusual pattern of deep snows followed by rain and then a hard freeze. This resulted in snow with a hard crust. Wolves could run easily on the surface of this snow, but the heavier-bodied moose broke through the crust. Thus the moose could not easily escape from wolves, nor could they effectively use their sharp, powerful hooves for defense. Under these conditions, the wolves could easily kill moose.

Around 1965, winters on Isle Royale returned to normal, and the wolves caught fewer moose. By the early 1980's, the moose population had again become extremely large, even though the wolf population had also grown. Then the wolf population began to decline, despite the abundance of moose. By the late 1980's, ecologists feared that wolves might disappear from Isle Royale. All of these population changes forced ecologists to reevaluate their thinking about how predators and prey control one another's populations. Ecologists recognized that although wolves and moose certainly can influence the size of each other's populations, these animal groups can completely determine one another's population size only under unusual circumstances.

In the 1990's, Isle Royale's moose population declined again. Ecological studies indicated that changes in the availability of food plants and nutrients were important factors in this decline. For example, the moose would eat the leaves of aspen trees, but not the unpleasant-tasting needles from spruce and fir trees. And since spruce and fir needles also did not taste good to the island's decomposers, the needles piled up on the forest floor, trapping nitrogen and other nutrients from entering the soil. Thus the quality of the soil declined, and the growth of trees was stunted. This has meant less food for the moose and a decline in moose population.

As for the wolves of Isle Royale, it appears that inbreeding and diseases—not lack of moose—are behind the die-off of the population. Thus, predator-prey models of population control probably are oversimplifications, and what looks like a stable, balanced situation may in fact derive from the interaction of various changeable forces. Natural systems are filled with compensating mechanisms that help stabilize nature. Hence populations often need to be understood from the perspective of the entire ecosystem.

Applied ecology

Applied ecology is the use of ecological studies to achieve practical goals. These studies help us to preserve and manage natural resources and to protect the environment. Applied ecologists work with scientists from different fields to try to solve problems concerning the health and well-being of people, plants, and animals.

Ecologists are concerned about the rate at which people are depleting such nonrenewable resources as coal, gas, and petroleum, and about the pollution caused by their extensive use. Ecologists believe that if the human population continues to grow, such problems as depletion of fuels, pollution, deforestation, congestion, poverty, and the disruption of climate will also worsen. An increasing concern is the loss of natural ecosystems and their many species as more forests and grasslands are converted to farmland, urban areas, and wasteland.

Some people think that the studies and activities of ecologists conflict with people's economic interests. But ecologists believe that ecological knowledge is essential for long-term economic well-being. They point out that the maintenance of natural ecosystems provides many benefits to society. For example, if air and water supplies are clean, people will be healthier, and medical costs will decrease. In addition, many ecologists think we can use the principles of ecology, such as energy flow, to understand human economies better. Ecologists believe everyone should learn about ecology and the environment, so that people can live in greater harmony with the rest of the world. Charles A. S. Hall

Related articles in *World Book* include:

Adaptation
Air pollution
Animal
Balance of nature
Biodiversity
Conservation
Environment
Environmental pollution

Gaia	National park	Recycling	Wildlife conservation
Habitat	Phenology	Water pollution	
Limnology	Plant		

Outline

I. Populations
A. Factors that control populations
B. Factors that change populations
II. Communities
A. The role of a species
B. Changes in communities
III. Ecosystems
A. Energy flow
B. Cycling of materials
C. Changes in ecosystems
IV. Applied ecology

Questions

What role do *decomposers* play in a food chain?
What is primary succession and secondary succession?
How does phosphorus "leak out" of an ecosystem?
What are some limiting factors of populations?
Why do many ecologists feel it is important to limit human population growth?
What is the difference between a community and an ecosystem?
What is an *ecological niche*?
Why do ecological pyramids develop?
What makes up the abiotic environment?

Additional resources

Kareiva, Peter M., ed. *Exploring Ecology and Its Applications.* Sinauer, 1997.
Kormondy, Edward J. *Concepts of Ecology.* 4th ed. Prentice Hall, 1996.
Scott, Michael M. *The Young Oxford Book of Ecology.* 1994. Reprint. Oxford, 1998. Younger readers.
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Econometrics, *ih KAHN uh MEHT rihks,* is the branch of economics that applies mathematics and statistics to economic theory. Business and government use econometrics to analyze and to predict economic activity.

Econometrics puts economic relationships into mathematical form and uses statistical data to try to make those relationships operational. For example, econometricians might believe that a person's income determines how much he or she spends. Econometricians would express this relationship in a general formula. They would then study data from various time periods and groups of people to see how income affects spending. They might determine that each $10 rise in income brings an $8 increase in spending.

Econometricians often develop a set of such formulas, called a *model,* establishing relationships among various economic factors. Models may describe the economy of a city, a nation, or the world. Econometricians use computers to store data and make calculations.

As early as the 1600's, the English economist Sir William Petty stressed the use of mathematics and statistics in economics. In the late 1800's, the French economist Léon Walras laid the foundation for econometrics with his mathematical description of the market economy. In 1969, the econometricians Ragnar Frisch of Norway and Jan Tinbergen of the Netherlands won the first Nobel Prize awarded for economics. Another econometrician, Lawrence R. Klein of the United States, won the 1980 Nobel Prize for economics. Thomas F. Dernburg

Economic Advisers, Council of, is a three-member group that advises the president of the United States on economic policies. The council reports to the president on current economic conditions, and it predicts future economic activity. It also helps the president prepare economic reports to Congress. In addition, the council works to increase cooperation among various government agencies by advising them on economic policies.

Congress established the council in 1946 in an effort to promote the nation's economic growth and stability. The council studies problems concerning the national economy and suggests ways for the president to deal with them. Such problems include unemployment and any decrease in the purchasing power of the nation's money. The president appoints the members of the Council of Economic Advisers, subject to Senate approval. Louis W. Stern

Economic determinism is a theory for interpreting history which states that a society's economic system shapes its social, political, and religious institutions. The German social philosopher Karl Marx first fully developed the theory in the mid-1800's, though other thinkers had introduced the idea earlier. It became one of the essential principles of his political philosophy, generally known as *Marxism.*

Marx rejected the idea that individuals, religion, or other factors cause political changes in society. Instead, he attempted to show that political changes result only from alterations in how a society produces and distributes goods and services. For example, he believed the political systems of capitalistic countries resulted from the growth of factories and other economic developments. Capitalistic countries include the United States, Canada, and many European nations.

Economic determinism also is related to Marx's theory of *class struggle,* which regards conflict between classes as inevitable. According to Marx, a society's economic system shapes its class structure. The class with the greatest economic power also possesses the greatest political power. Therefore, classes with little political strength can gain power only by changing the economic system. Richard C. Wiles

See also **Communism** (The ideas of Marx); **Marx, Karl.**

Economics is the study of how goods and services get produced and how they are distributed. By *goods and services,* economists mean everything that can be bought and sold. By *produced,* they mean the processing and making of goods and services. By *distributed,* they mean the way goods and services are divided among people.

Most people want more than they can afford to buy. If a family buys one thing, they may not be able to afford something else they would like. The same is true of nations. Whether a nation is rich or poor, most of its people want more than they can afford. They seek better schools, more houses, and stronger armed forces. The field of economics studies how the things people need and want are made and brought to them. It also studies how people and nations choose the things they buy from among the many things they want.

In all countries, the resources used to produce goods and services are *scarce.* That is, no nation has enough farms, factories, or workers to produce everything that everyone would like. Money is also scarce. Few people have enough money to buy everything they want when they want it. Therefore, people everywhere must choose the best possible way to use their resources and money. Children may have to choose whether to spend their al-

Important terms in economics

Balance of payments is a statement of all goods, services, and investments or other money payments that flow in and out of a country during a given period.
Bond is a certificate issued by a government or a business company promising to pay back with interest money it has borrowed.
Boom is a period of rapid economic growth, when production, consumption, and employment are high and growing. A boom is also called a period of prosperity.
Capital refers to factories, equipment, and property, other than land, that can be used to produce wealth. It also means money used to buy these things.
Capital goods are goods that can be used to produce more goods in the future.
Capitalism is an economic model that calls for the ownership and direction of most productive resources by private individuals. Economies based on the principles of capitalism are often called *free enterprise* economies.
Central planning is an economic model that calls for government control of all important economic activities.
Competition exists when a number of people try to sell similar goods to the same buyers.
Consumer goods and services are goods and services produced for current use by individuals and families. They include such goods as food and clothing and such services as medical care and education.
Consumption is the act of using consumer goods and services.
Corporation is a business organization formed and owned by a number of people. These people are known as *stockholders.*
Cost of living is the cost of buying the goods and services used in daily living.
Depression is an extended slump in business activity.
Distribution is the process by which goods and services are divided among consumers.
Exchange rate is the price of one nation's currency in terms of another's currency.
Goods and services means everything bought and sold.
Gross domestic product is the value of all goods and services produced within a country during a given period, regardless of who owns the production facilities.
Gross national product is the value of all goods and services produced by a country during a given period, even if production facilities are in another country.
Income is money, goods, or services earned by labor or by the use of other resources.
Inflation is a continual increase in prices throughout a nation's economy.
Investment is the use of money to provide income or profit. Investment also means money that is spent on capital goods. The capital goods themselves are also considered an investment.
Labor force includes all the men and women who are employed, or who are seeking paid work.
Laissez faire is the theory that government should not interfere in most economic affairs.
Law of demand states that the price of a product rises as demand for the product increases, if other forces do not change.
Law of supply states that the price of a product falls as the supply of it increases, if other forces do not change.
Macroeconomics is a branch of economics concerned with the economy as a whole, including total production, overall employment, and general price levels.
Microeconomics is a branch of economics concerned with the activities of individual consumers and producers.
Money is anything that people agree to use to pay for goods and services.
Monopoly exists when there is only one seller of a product in a market.
National income is the total of all income earned in a nation during a given period.
Net income refers to business profit that remains after all costs of production have been paid.
Production is the process by which goods and services are made or prepared for use. A *producer* is someone who provides goods and services.
Productive resources are the elements used in production. They include natural resources, capital, a labor force, and technology.
Productivity is the ability to produce goods and services. Productivity increases when a larger amount of goods or services is produced by using the same amount of resources.
Profits are earnings of a business over and above all costs.
Recession is a period of decreased business activity. During a recession, production, consumption, and employment are lower than they are during prosperity, but not as low as during a depression.
Standard of living usually refers to the economic level at which an individual, family, or nation lives. Economists sometimes measure this level by determining the value of the goods and services produced or consumed by the individual, family, or nation during a given period.
Tariff is a tax on imported or exported goods.

lowance on a motion picture or a hamburger. Storekeepers may have to choose whether to take a summer vacation or to use their savings to buy more merchandise. A nation may have to choose whether to use tax money to build more highways or more submarines. In economic terms, the children, the storekeepers, and the nation all must *economize* to satisfy their most important needs and wants. This means they must try to use the resources they have to produce the goods and services they most want.

Economic problems

Every nation must organize the production and distribution of goods and services that its citizens want. To do this, a nation's economy must solve four basic problems: (1) What shall be produced? (2) How shall goods and services be produced? (3) Who shall get the goods and services? and (4) How fast shall the economy grow?

What shall be produced? No nation can produce enough goods and services to satisfy all its people. But which goods and services are most important? Should land be used to raise corn or wheat? Should factories be used to produce rockets or television sets?

How shall goods and services be produced? Should each family raise its own food and make its own clothing? Or should special industries be developed to provide these products? Should many workers be used in an industry? Or should machines do many jobs?

Who shall get the goods and services? Should everyone have an equal share of goods and services? Which goods and services should go only to people who can afford to buy them? Which goods and services should be distributed in some other way?

How fast shall the economy grow? An economy grows when it produces goods and services at an increasing rate. A nation must decide what proportion of its scarce resources should be used to build factories and machines and provide more education for its

young people, all of which will increase future production. How much of a nation's resources should be used to produce goods and services for immediate use? In addition, the nation must decide how to avoid unemployment and other economic setbacks that waste resources.

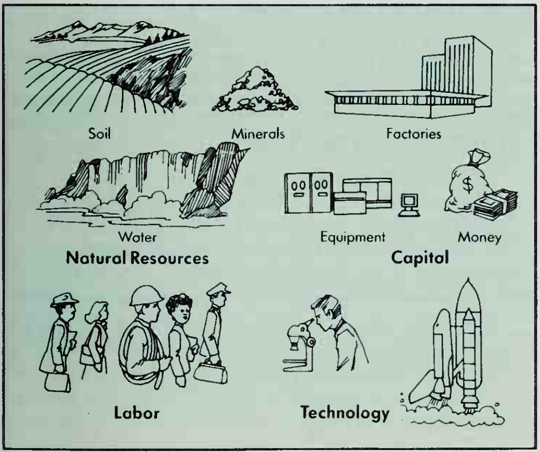
How the economy grows

An economy must grow to provide people with an increasing *standard of living*—that is, more and better goods and services. In general, the faster a country's economy grows, the faster its standard of living rises.

Making the economy grow. Four main elements make it possible for nations to produce goods and services. These elements, called *productive resources,* are: (1) natural resources, (2) capital, (3) a labor force, and (4) technology. Economists define *natural resources* as all land and raw materials, such as minerals, water, and sunlight. *Capital* includes factories, tools, supplies, and equipment. The word *capital* also means the money that can be used to buy these items. *Labor force* means all people who work or are seeking work, and their education and skills. *Technology* refers to scientific and business research and inventions.

To grow, a nation's economy must add to its productive resources or improve the way it uses them. For example, an economy could grow if the nation used some of its resources to build factories, heavy equipment, and other *capital goods.* These capital goods could then help increase future production. In addition, a nation might train scientists, create new technologies, educate workers, or train business managers to direct future production. The knowledge of these people is known as *human capital.* New technology and improved human capital could *increase productivity*—that is, produce more units of goods or services for each unit of resources consumed in production.

Measuring economic growth. The value of all goods and services produced within a country during a year makes up a nation's *gross domestic product,* or *GDP* (see **Gross domestic product**). A nation measures its economic growth by the change in GDP over a period of years. Since the mid-1970's, the *real GDP* of the United States—that is, GDP adjusted for inflation—has increased at an average rate of about 2 percent each year.



WORLD BOOK illustrations by Bill and Judie Anderson

Productive resources are the main elements that make it possible for nations to produce goods and services. These elements are natural resources, capital, labor, and technology.

Kinds of economies

Different kinds of economies have developed as nations have tried different approaches to solving their basic economic problems. However, the economies of all nations mix elements from two main economic models. These models are (1) capitalism and (2) central planning.

Capitalism calls for the ownership and control of all major businesses by private individuals. Many economies are based on the principles of capitalism. These economies are called *free enterprise* or *free market* economies because they allow people to carry out most economic activities free from government control. Even in these countries, however, the government owns some land and capital and exercises some control over the economy. The section on *The United States economy* later in this article describes how an economy based on capitalism works. See also **Capitalism.**

The Scottish economist Adam Smith first stated the principles of capitalism in the 1700's. Smith believed that governments should not interfere in most business affairs. He said the desire of business people to earn a profit, when regulated by competition, would work almost like an "invisible hand" to produce what consumers want. Smith's philosophy is known as *laissez faire* (noninterference). See **Laissez faire.**

Central planning calls for government control of all major economic activities and government ownership of nearly all productive resources. It calls for giving government planners control of the production, pricing, and distribution of goods and services.

Variations among countries. All real economies combine elements of capitalism with those of central planning. However, nations differ from one another in the extent to which they rely on the two approaches. The United States and Canada have economic systems that use relatively little government control. For this reason, their economies are often described as capitalist.

The Soviet Union and many nations of Eastern Europe once relied heavily on central planning. The governments of such countries owned nearly all productive resources and controlled all important economic activities. Government officials made all key decisions about how goods were produced, priced, and distributed. The economic system used by these countries was often referred to as Communism. No nation where this system was used prospered. The Eastern European countries sharply reduced their reliance on central planning after a series of revolutions in the late 1980's and early 1990's. Also in the late 1980's, the Soviet Union began to decrease government control of its economy. In 1991, the Soviet Union was dissolved, and afterward many of the former Soviet republics continued to reduce their reliance on central planning.

China and other countries that are often thought of as Communist have also loosened control over economic activities. In the mid-1980's, for instance, the government of China began to relax its control over business activity and prices.

Many other nations have economic systems that use more central planning than the United States does but less than the Soviet Union and the Eastern European countries did. In these nations, the government may own and run such important industries as steel mills, coal mines, and railroads. Many other industries are privately owned. Countries of this type include the United Kingdom and Sweden.

The United States economy

Every day, millions of men and women in the United States work on farms and in factories and offices. These men and women produce trillions of dollars worth of goods and services each year. The government does not tell the people where to work. It does not decide where most of the factories should be built. Nor does the government dictate what prices will be charged for most goods and services. Yet the work is done, the prices are set, and most Americans get the products they need.

How does the economy work with so little planning? The desire of most people to improve their own welfare makes it work. In the United States, people are free to improve their economic standing. They may try to find a job where they please and generally may spend their income as they wish. Of course, the government takes part in many economic activities. But for the most part, individuals and private businesses run the American economy. That is, people act as consumers, workers, and managers. Individuals and private businesses, along with other institutions, make their own economic decisions. These decisions shape and are shaped by such economic forces as supply and demand, profits, markets, prices, competition, and the distribution of income.

Consumers use goods and services, and include individuals and government agencies. In the United States, consumers jointly determine "what shall be produced?" by the things they choose to buy. Economists use the terms *supply* and *demand* to help explain how consumers influence production. Suppose that thousands of people begin to buy a new compact disc. Stores must order more copies of this compact disc from the company that makes it, and the company must produce more copies of it. The company produces a larger quantity of compact discs, thereby increasing the supply of them in the economy, because people have increased their demand for them. If, a few months later, people buy fewer copies of the compact disc, the stores would order fewer from the company. The company would then produce fewer copies. See **Supply and demand**.

Business and profits. Many kinds of businesses produce the things consumers want. One person may own and operate a small business, such as a barbershop or a service station. Two or more people may form a partnership to carry on a business. Other businesses may be large corporations owned by many people. Some businesses produce goods, such as bread or suits. Other businesses produce services, such as transportation or TV shows.

The main goal of most businesses is to earn *profits.* Profits are earnings over and above all costs. The cost of producing a suit includes the cost of the cloth, the wages of the workers who make the suit, the expense of buying tools and machinery, the cost of advertising, and so on. The price of the suit must include all these costs—plus a profit for the company that makes it.

The desire to earn a profit causes business executives to produce and sell goods and services that consumers demand. The *profit motive* influences executives to organize and operate their firms efficiently. By doing so, they can cut production costs and thus increase profits. Executives help determine "how shall goods and services be produced?" by the way they organize production to make profits. See **Business; Profit**.

Most hospitals, universities, charitable organizations, and similar institutions do not try to earn profits for their owners. They may engage in activities that profit-seeking businesses would not be able to pursue. Some of these *nonprofit institutions* sell their goods and services. Others give them away. Nevertheless, their managers generally try to produce goods and services efficiently.

Markets, prices, and competition. Whenever goods and services are bought and sold, a *market* is created. A market may be a neighborhood store or a worldwide stock market. In large markets, most buyers and sellers never see each other. They may conduct their business by telephone, facsimile, or computer.

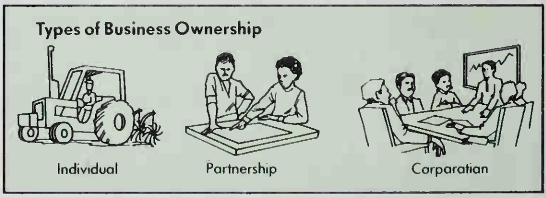
In the U.S. economy, market prices rise and fall as demand or supply increases and decreases. Suppose that 100,000 families want to buy new automobiles, but only 90,000 cars have been produced. The quantity demanded is greater than the quantity supplied. Sellers might guess that many families would be willing to pay more for one of the limited number of automobiles. As a result, the sellers might raise the prices of automobiles. At the same time, manufacturers would begin to produce more automobiles in order to sell more and increase profits. Eventually, as more automobiles were produced, the quantity supplied would begin to catch up with the quantity demanded. See **Price**.

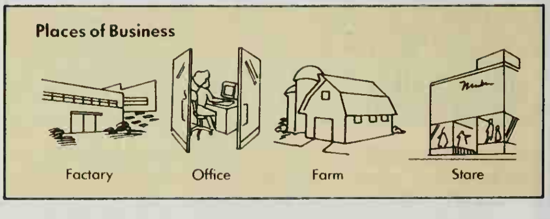
In the U.S. economy, businesses that provide similar products compete with one another for buyers. As a result, competition causes businesses to charge reasonable prices and keep quality high. For example, if a store

Businesses and the economy

Various kinds of businesses participate in the economy of the United States. They earn profits by selling the different goods and services that consumers need and want.

WORLD BOOK illustrations by Bill and Judie Anderson

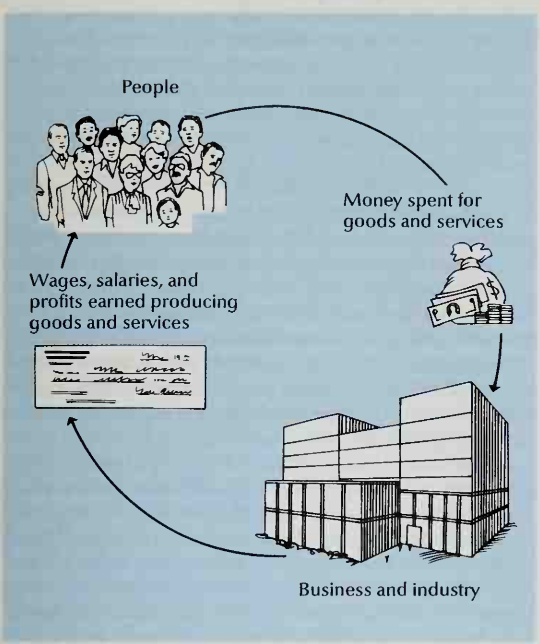


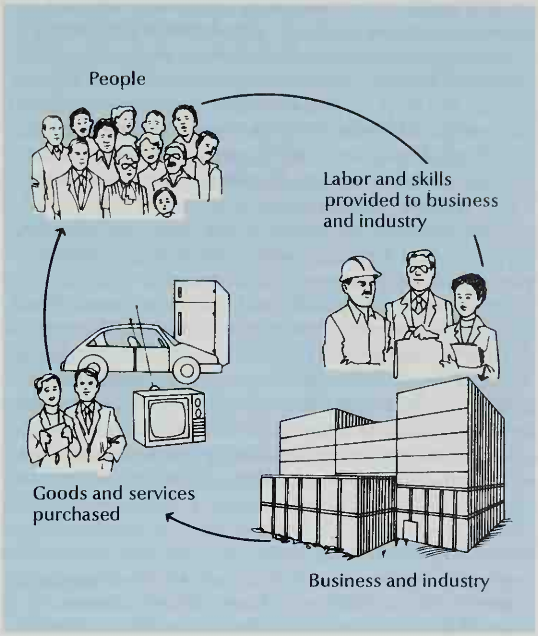


The pattern of the economy

The distribution of money, goods, and services makes up the pattern of the United States economy. The circle at the left illustrates how money flows from people to industry, and then back to the people. The circle at the right shows how people use their skills to produce goods and services. The finished goods and services then move from industry back to the people.

WORLD BOOK diagrams by Bill and Judie Anderson





raises its price for a bag of sugar, its customers may choose to buy from a store that offers the same amount of sugar at a lower price. Similarly, a business that offers consumers products of low quality may lose customers to businesses that supply products of higher quality.

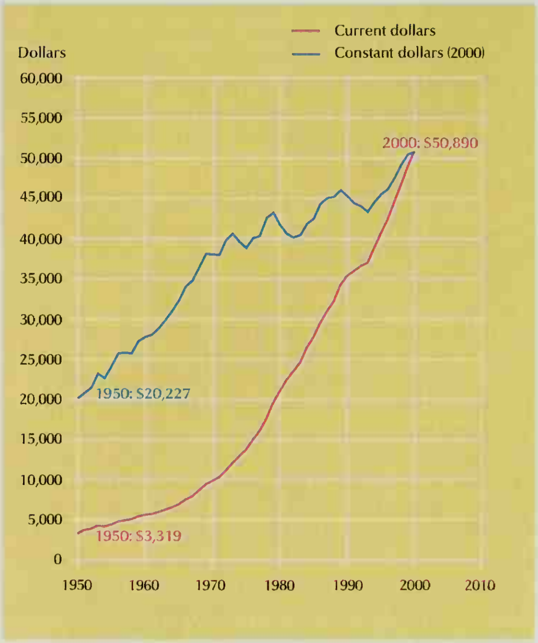
Competition is so important to the American economy that the government has passed many laws to enforce it. These laws prohibit agreements among sellers that interfere with competition. Some laws forbid most *monopolies.* A monopoly is a company that controls the supply of a unique product. Other laws prohibit most *cartels* and some *trusts,* which are combinations of businesses that control all or most of a particular industry and that act together rather than compete with one another. See **Antitrust laws; Cartel; Monopoly and competition.**

Distribution of incomes. In the United States, "who shall get the goods and services produced?" depends mostly on who can afford to buy them. And the amount of goods and services people can afford depends mainly on the size of the income they receive.

People earn income in a variety of ways. Most people receive income as wages or as salaries in exchange for their work. Businesses receive income in the form of profits, which belong to the owners. A corporation is owned by people who buy shares of stock and usually receive income in the form of dividends (see **Stock, Capital**). Owners of land and buildings receive rent. Owners of bonds and savings accounts receive interest (see **Interest**). Many people receive income from government programs, such as Social Security and veterans payments. The total amount of all incomes received in a

Family income in the United States

This graph shows how median family income in the United States has risen. The median is the middle value in the range of all incomes. The constant dollars line shows what the current dollars line would look like without the effect of inflation.



Source: U.S. Census Bureau.

country is called the *national income.* In the United States, wages, salaries, and employee benefits make up most of the national income. See **National income.**

In the United States, people earn income by producing the goods and services that consumers demand. In general, the more a person contributes to producing the things consumers want, the larger the person's income will be. The forces of supply and demand also influence the size of a person's income. For example, a firm would probably pay factory managers more money than it would pay unskilled laborers. The firm pays managers more because they contribute more to earning the company's profits than do unskilled workers.

In many industries, workers have joined together to try to increase their incomes. Through *labor unions,* workers bargain with employers to determine wages, hours of work, safety rules, and other conditions. Workers in some industries are protected by *minimum wage laws,* which are passed by federal or state governments. Minimum wage laws set the smallest amount of money that an employer can pay a worker for doing an hour's worth of work. See **Labor movement; Minimum wage.**

In all economies, private savings and investment have an important influence on economic growth. When people save part of their income, they spend less money on consumer goods and services. More money is then available for the construction of machines and factories. People who save may put money in banks, which lend to businesses. Or the savers may invest in stocks and bonds sold by corporations. With the money of savers, businesses can increase their spending on capital goods. In the U.S. system, "how fast shall the economy grow?" depends greatly on how much consumers and business companies save and invest. See **Investment.**

Growth of U.S. productivity

Improved technology in the United States has increased productivity. A worker in 1998 produced almost three times as much per working hour as a worker in 1947. This graph estimates the average value of goods and services produced per person per hour in constant dollars. Constant dollars factor out the effects of inflation from year to year.

Sources: *World Book* estimates based on data from U.S. Bureau of Economic Analysis and U.S. Bureau of Labor Statistics.

Government and the U.S. economy

The government takes part in many important economic activities in the United States, even though the U.S. economy is based chiefly on the principles of capitalism. The federal, state, and local governments have four major roles in the economy. These governments (1) establish and enforce laws that affect economic activity, (2) set up public utilities, (3) provide goods and services for the public, and (4) work for economic stability. Economists disagree on how far the government should go in carrying out each role.

Laws. In the United States, the people depend on the government to pass laws that assure economic fair play. These laws aim at preventing individuals and business companies from taking unfair advantage of each other.

Many of the most important laws governing the U.S. economy concern business competition. Other laws ban harmful or misleading advertising. Still others set standards for working conditions, set minimum wages, and prohibit businesses from refusing to hire people or lend money to them because of their race, sex, or age. The U.S. government also issues regulations designed to protect the environment. States issue charters that allow companies to operate. Local zoning laws permit businesses to operate only in specific areas and ban them from residential neighborhoods.

The federal, state, and local governments have agencies that enforce economic rules. For example, the Federal Trade Commission investigates business activities and can force a company to give up unlawful business practices. See **Federal Trade Commission.**

Public utilities are companies that provide services essential to the public. These services include electric power, water, gas, sewerage, and local telephone service. In many public utility businesses, competition would be wasteful. Competition may result in higher prices because each of the competing companies may have to buy the same type of expensive equipment while serving fewer customers than would be served by a single, protected company.

The government grants *legal monopolies* to public utility companies so they may operate without competition. But federal and state agencies regulate the prices and standards of service of most public utilities. For example, the Federal Communications Commission supervises telephone companies. The Department of Energy has authority over electric power companies and natural gas companies. Governments may own and operate some public utilities themselves. See **Public utility.**

Public services. Governments on all levels provide many services that could not be furnished as well by private companies. These services include police and fire protection, public health programs, national defense,

postal services, and roads and streets. Governments at federal, state, and local levels also offer *welfare programs.* These programs, often called *public assistance,* offer medical services, public housing, and other economic aid to needy people. See **Welfare.**

Some people in the United States receive financial aid from social insurance, or social security, programs. These programs are financed by special taxes on workers and employers. They replace income lost because of retirement, unemployment, disability, or death of a provider. They also help most elderly and disabled people pay for medical care. See **Social security.**

All the goods, services, and income assistance provided by government make up the *public sector* of the economy. In the United States, government revenues and spending equal about one-third of the nation's gross domestic product. Governments pay for most of the services that they provide with money they collect in taxes. There are many kinds of taxes. For example, individuals and corporations pay *income taxes* on their earnings. Consumers pay *sales taxes* on many items they buy. Owners of land and real estate pay *property taxes.* See **Taxation.**

Economic stability. The U.S. economy has grown rapidly at times. Today, Americans enjoy one of the world's highest standards of living. There have also been periods when the economy did not grow. In some ways, tracing the growth of the U.S. economy is like following the path of a roller coaster. Sometimes the economy zooms to great heights of prosperity. At other times, many workers cannot find work and factories are idle. Periods of above average business activity are called *booms.* Brief and small declines in business activity are known as *recessions.* Lengthy and large drops are called *depressions.*

During a boom, total production and employment rise. Consumer demand for goods and services increases, and companies invest in new equipment that will increase production. But production cannot always keep up with consumer spending during a boom. If the supply of goods and services rises less than the demand for them, a nation may experience a period of *inflation* (rapidly rising prices). If inflation becomes extreme, prices may rise so high that many people cannot afford products they need. See **Inflation.**

Production falls during a recession and drops sharply during a depression. At such times, numerous people lose their jobs. Business profits fall, and many firms go bankrupt. See **Depression; Recession.**

Until the 1930's, the government made few attempts to control booms and depressions. Most people thought these periods should be allowed to run their course without government interference. But since the Great Depression of the 1930's, the government has worked to promote economic stability.

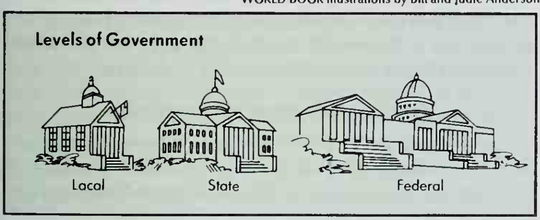
Sometimes the government may use its own economic power to help check inflation and depression. During a depression, the government may increase its spending on goods and services and on income assistance for unemployed people and others. It may build new public buildings or improve major highways. This additional spending aims to create jobs for unemployed people. Government spending also attempts to increase the general demand for goods and services. Increased demand encourages business activity. The government may also try to increase demand by cutting taxes so that the people have more money to spend. During a boom, the government may try to curb inflation by cutting its own spending and thus reducing total demand. Or the government may try to reduce private spending by raising taxes. Then people would have less money to spend on goods and services.

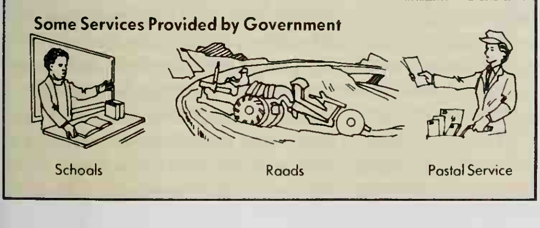
In recent years, however, the government has worked for economic stability mainly through the Federal Reserve System (FRS), the central banking organization of the United States. All national banks and some state banks belong to the system. The FRS helps manage the nation's economy by influencing interest rates and the availability of money and loans. To maintain high employment, the FRS may pursue policies that lower interest rates and thus encourage borrowing and spending. If inflation threatens the economy, the FRS may adopt policies that increase interest rates. See **Federal Reserve System.**

Government participation in the economy

In the United States, all levels of government regulate business activities. These governments also provide public services that could not be furnished as well by private companies.

WORLD BOOK illustrations by Bill and Judie Anderson





The world economy

Through world trade and finance, the United States and other nations depend on one another for many vital goods and services. Economists study economic relations among nations. They look for ways to increase international trade. Economists also try to help poor countries improve their economic conditions.

World trade. Nations can gain by trading with one another because the resources of the world are not distributed evenly. For example, Australia has excellent grazing land for livestock, and Chile has rich mineral deposits. World production would increase if nations produced only the goods they could provide relatively easily and imported the goods that were relatively difficult for them to produce.

Despite the advantages of world trade, nations have tried to limit imports and produce many of their own goods and services for hundreds of years. Many nations fear that specializing in a few products would make

them too dependent on other countries. In case of war, their supplies of essential goods and services might be cut off. Business people often argue that their industries should be protected from foreign competition. Otherwise, they say, foreign producers might gain monopolies over certain products and raise prices. Many people insist that a nation can increase employment and help avoid depressions by limiting imports and developing its own industries.

Nations use many methods to restrict trade. The two most important methods are (1) tariffs on imports and (2) nontariff barriers. A *tariff* is a tax on imports or exports. When placed on imports, tariffs raise the price of products from other countries. *Nontariff barriers* consist of other regulations or restrictions on trade between nations. *Import quotas,* for example, allow only a certain quantity of an item to be imported each year.

Many nations work to increase unrestricted trade, called *free trade.* These nations say that free trade not only offers economic advantages but also increases international understanding. Free-trading nations must cooperate because they depend on one another for goods and services.

Two or more nations may reach a free-trade agreement with one another. In 1992, for example, the United States, Canada, and Mexico signed the North American Free Trade Agreement (NAFTA). This pact called for the gradual elimination of tariffs and certain other trade barriers between the three nations. After ratification by the national legislatures of the three countries, NAFTA went into effect on Jan. 1, 1994. See **North American Free Trade Agreement.**

Many nations continue to impose trade restrictions on one another. Less-developed countries, for instance, still rely on high tariffs to protect their industries. See **Exports and imports; Free trade; International trade; Tariff; Trade.**

World finance. Trade within a country involves only one kind of currency, such as dollars in the United States or pounds in the United Kingdom. Trade among countries may involve several kinds of currencies. For this reason, business firms and governments use an international system of banking and finance to exchange one kind of currency for another.

Suppose an American importer owes a British manufacturer 1,000 pounds for a shipment of English bicycles. The importer pays the manufacturer with a special kind of check for 1,000 pounds. This check is called a *foreign bill of exchange.* The importer buys the check from a bank or some other foreign-exchange dealer. The price in dollars that the importer pays for the foreign exchange depends on the current *exchange rate* for British pounds. An exchange rate is the price of one currency in the terms of another currency. See **Exchange rate.**

Until the early 1970's, the governments of most nations specified the rate of exchange for their currencies. Sometimes governments *devalued* (lowered the value of) their money in an effort to increase foreign sales. But in the early 1970's, some nations adopted a system of *floating exchange rates.* Under this system, the price of a nation's currency changes in relation to the world demand for it. If the demand for British pounds goes up, the price of the pound goes up. If the demand for British pounds falls, the price falls. See **Devaluation.**

Most nations keep records of their commercial and financial dealings with other nations. The total amount of goods and services plus money and gold that flow into and out of a country during a given period makes up the country's *balance of payments.* If a country pays out more money to other countries than it receives from other countries, it has a *deficit* in its balance of payments. If a country receives more money than it spends, it has a *surplus* in its balance of payments.

From the end of World War II in 1945 until the early 1980's, the United States sold more goods and services to other nations than it bought from them. This surplus in international trade ended in 1983. Since that year, the United States has been unable to sell as much abroad as it buys and has experienced large trade deficits. See **Balance of payments.**

Developing economies. About three-fourths of the world's people live in developing countries. Most such nations are in Africa, Asia, and Latin America, and are poor. In a developing country, many people have barely enough to eat. They live in crude houses and have few clothes. Most of the people in such countries are farmers. But they have few agricultural tools or machines to develop the land.

Poverty and overpopulation make it difficult to improve conditions in developing areas. The people use what little resources they have just trying to keep alive. Few resources are then available to invest in factories, equipment, schools, and highways. In many areas, the population grows so quickly that there is not enough land or natural resources to support all the people. And many of the people in such areas lack the knowledge and skills that are necessary to make the best use of their resources.

Many wealthier nations are helping the developing countries improve their economies. For example, the United States has given billions of dollars in loans and gifts to needy nations. American and European businesses have invested large sums in building industries in poorer countries. Many nations have also developed technical assistance programs. Under these programs, experts visit developing nations to train and educate the people.

Largely through their own efforts, some developing countries have enjoyed rapid economic growth. For example, the economies of Brazil, South Korea, Mexico, and Singapore are among the most rapidly growing economies in the world. See **Foreign aid; Technical assistance; Peace Corps; Alliance for Progress.**

The development of economics

Early theories. People have been interested in economic problems since early times. But the first major theories about a nation's economy were not developed until the 1500's, the beginning of the period of *mercantilism.* The mercantilists believed a government should regulate economic activities to establish a favorable balance of trade. They said nations could increase their supply of money by exporting more products than they imported. Most mercantilists favored high tariffs and other barriers to limit imports. See **Mercantilism.**

During the 1700's, a group of French writers known as *physiocrats* attacked mercantilism. The physiocrats believed that governments should interfere less in eco-

nomic life. They were the first economists to use the term *laissez faire* to mean noninterference by the government. The physiocrats also began the first organized study of how economies work.

The classical economists. Most economists today consider Adam Smith of Scotland to be the father of modern economics. Smith built on some of the ideas of the physiocrats. But he had a much better understanding of economic activities. Smith's book *The Wealth of Nations* (1776) includes many ideas that economists still accept as the basis for private enterprise. Smith believed that free competition and free trade help an economy grow. He said the government's main role in economic life should be to assure effective competition.

Smith lived during the time of the American and French revolutions. His emphasis on economic freedom suited the belief in political freedom that was growing during that period. People began to accept Smith's ideas and to develop new theories about private enterprise. Smith and his followers became known as *classical economists.*

Three British economists of the late 1700's and the 1800's wrote particularly influential works. David Ricardo produced strong arguments for free trade among nations. Thomas Robert Malthus challenged some of Smith's ideas but developed others further. Malthus warned that if populations continued to grow, nations someday would not be able to produce enough to feed all the people. John Stuart Mill proposed that profits be divided more equally among employers and workers.

Karl Marx and Communism. Some writers disagreed with the idea that competition would lead to economic progress. The most influential was Karl Marx, a German philosopher of the 1800's. In his book *Das Kapital* (*Capital*), Marx interpreted human history as a struggle between the ruling class and the working class. The first volume of the book was published in 1867. In *Das Kapital,* Marx declared that free enterprise would lead to increasingly severe depressions, and eventually to a revolution by the workers. In the *Communist Manifesto* (1848), Marx and German philosopher Friedrich Engels had urged workers to rebel against their employers. They called for an economy in which the government would own all the property. Marx's theories provided the basis for Communism.

New solutions for old problems. During the late 1800's and the early 1900's, economists began to use scientific methods to study economic problems. In France, Léon Walras worked out a mathematical statement to show how each part of an economy is related to all the other parts. Wesley Clair Mitchell, an American, urged economists to use statistics in testing their theories. Mitchell also studied booms and depressions.

The Great Depression of the 1930's caused a number of economists to seek a new explanation of depressions. John Maynard Keynes, a British economist, attacked the idea that free markets always lead to prosperity and full employment. In *The General Theory of Employment, Interest, and Money* (1936), he suggested governments could help end depressions by increasing their spending. Other economists began to study ways to measure economic activity. Simon Kuznets and other U.S. economists developed methods of measuring gross national product, national income, and other economic factors.

During the 1960's and 1970's, a group of economists called *monetarists* rejected many of the theories of Keynes and his followers. Instead, the monetarists urged that governments increase the money supply at a constant rate to stabilize prices and promote economic growth. Milton Friedman, an American economist, became the leading spokesman for monetarism.

Research today generally centers around understanding the relationships between various parts of the economy. Economists base their findings on observation, on case studies, and on other methods of research. Many economists emphasize the use of mathematics and statistics in testing economic theories. Their method is known as *econometrics.* The methods of economic analysis have been applied to many problems that may seem unrelated to production, such as education, family life, and the organization of governments.

Careers in economics

Economists find many career opportunities in business and government. Many economists teach and do research at colleges and universities.

Economists may specialize in one or more areas of economics. *Industrial economists* study various forms of business organization. They analyze production costs, markets, and investment problems. An *agricultural economist* specializes in the study of such areas as farm management and crop production. A *labor economist* is concerned with wages and hours, labor unions, and government labor policies. Other fields of economics include taxes, banking and finance, international trade, economic theory, and comparative economic systems. In addition to professional economists, thousands of people do statistical and clerical work in connection with economic problems.

A college degree in economics, business administration, or mathematics is desirable for a career in the field of economics. College students who major in economics take several general courses in their subject. In addition, they take certain special courses. Such special courses may include those in labor problems, income distribution, public finance, and money and banking. Students of economics also take courses in such related fields as history, political science, and statistics.

Some companies and government agencies require graduate training in economics. Generally, people who want to teach economics at a college or university must have obtained at least a master's degree. Many colleges and universities require their economics professors to have a doctor's degree.

Anyone interested in a career in economics may obtain information from the American Economic Association, which is located in Nashville. More than 25,000 members belong to this professional organization. The Joint Council on Economic Education, located in New York City, also offers career information.

Henry J. Aaron

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Outline

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VII. The development of economics
VIII. Careers in economics

Questions

How do supply and demand influence prices?
What is the meaning of (1) *profit*? (2) *capital goods*? (3) *balance of payments*?
What are the four basic problems of the economic system of a country?
Why is competition an important part of an economy based on capitalism?
How does the government work to achieve economic stability?
What four main elements make production possible?
When might a nation experience a period of inflation?
How do booms and depressions affect the economy?
Who is the father of modern economics?
What are the two chief ways nations restrict trade?

Additional resources

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Ecosystem. See Ecology.

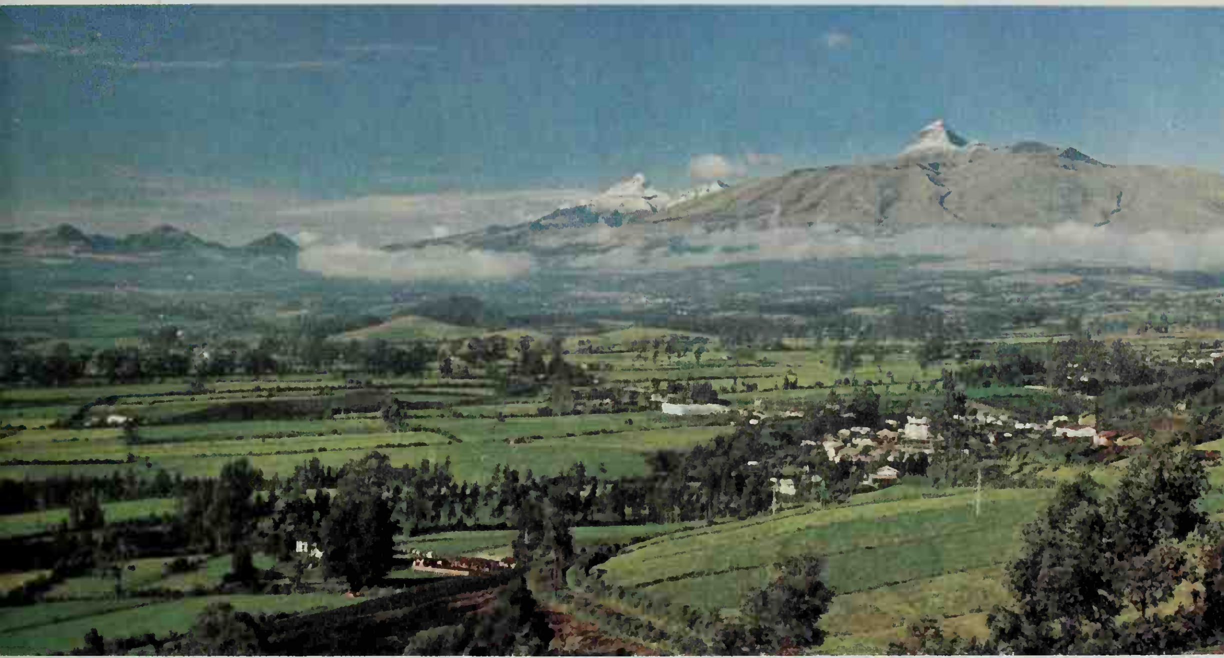
Ecstasy is the common name for a synthetic drug that has stimulant and hallucinogenic properties. Taken in pill form, it is commonly used at large, all-night dance parties known as *raves.* The drug produces feelings of relaxation, decreased anxiety, and heightened senses. Ecstasy also causes muscle tension, increased heart rate and blood pressure, and sweating. These symptoms, when combined with the vigorous physical activity of dancing, can lead to severe dehydration, heart or kidney failure, and even death. Ecstasy is also known as MDMA, for its chemical name, 3-4 *m*ethylene*d*ioxy*m*eth*a*mphetamine.

Short-term use of Ecstasy may cause confusion, depression, sleep problems, anxiety, and paranoia. These symptoms can last for weeks after taking the drug. Scientists have found that Ecstasy damages neurons in the brain that produce *serotonin,* one of the brain's most important messenger chemicals. Serotonin helps regulate mood, aggression, sleep, and sexual activity. Long-term use of Ecstasy can cause damage to the brain in areas that control thought, memory, and learning.

The production, possession, distribution, and sale of Ecstasy is prohibited in the United States and most other countries. The drug is often produced in illegal, makeshift laboratories and can contain impurities, including dangerous chemicals. Paula DeGraffenreid Riggs

See also **Drug abuse.**

Ectoplasm. See **Cell** (The cytoplasm).



Bob Kelly, Photo Researchers

Snow-capped peaks of the Andes Mountains rise along the edges of a high plateau in central Ecuador. About half of Ecuador's people live on the plateaus and in the valleys of the Andes.

Ecuador

Ecuador, *EHK wuh dawr,* is one of the smallest countries of South America. It lies on the west coast of the continent between Colombia and Peru. The equator crosses Ecuador and gives the country its name. *Ecuador* is the Spanish word for *equator.*

Ecuador has important petroleum deposits, and oil ranks as the country's leading export. However, agriculture employs more of the Ecuadorean labor force than does any other economic activity. Many of the nation's farmers still use old-fashioned farming equipment and methods.

The Andes Mountains rise through much of central Ecuador. About half the people live in the valleys and on the plateaus of the Andes. Quito, Ecuador's capital, lies more than 9,000 feet (2,700 meters) above sea level on an Andean plateau.

A flat, partly forested, tropical plain extends west of the Andes along the Pacific Ocean. This coastal plain is developing faster than any other part of the country. About half the Ecuadorean people live there. During the middle and late 1900's, many people moved to the coastal plain to farm its rich soil. Others have moved to the coastal city of Guayaquil to find jobs. Guayaquil is Ecuador's largest city. It is also the country's leading commercial center and chief seaport. East of the Andes Mountains is a large jungle. Few people live in this area.

The Galapagos Islands, a group of islands about 600 miles (970 kilometers) off the coast, belong to Ecuador. These islands are known for their strange animals and plants. The British biologist Charles R. Darwin studied

Murdo J. MacLeod, the contributor of this article, is Graduate Research Professor of History at the University of Florida and Associate Editor of Hispanic American Historical Review.

Facts in brief

Capital: Quito.
Official language: Spanish.
Official name: República del Ecuador (Republic of Ecuador).
Area: 109,484 mi² (283,561 km²). *Greatest distances*—north-south, 450 mi (724 km); east-west, 395 mi (636 km). *Coastline*—1,278 mi (2,057 km), including the Galapagos Islands.
Elevation: *Highest*—Chimborazo Volcano, in the Andes Mountains, 20,561 ft (6,267 m) above sea level. *Lowest*—sea level, along the coast.
Population: *Estimated 2002 population*—13,090,000; density, 120 per mi² (46 per km²); distribution, 63 percent urban, 37 percent rural. *1990 census*—9,648,189.
Chief products: *Agriculture*—bananas, beef, cacao, coffee, corn, milk, oranges, potatoes, rice, sugar cane, wheat. *Fishing*—herring, mackerel, shrimp. *Forestry*—balsa wood. *Manufacturing*—cement, drugs, processed foods, straw hats, textiles. *Mining*—petroleum.
National holiday: Independence Day, August 10.
National anthem: "Salve, O Patria" ("Hail, O Fatherland").
Money: *Basic unit*—United States dollar. One hundred cents equal one dollar.

Stephanie Dinkins, Photo Researchers

Quito, Ecuador's capital, lies on a plateau almost 2 miles (3 kilometers) above sea level. The city has many buildings and plazas constructed by the Spaniards when they ruled Ecuador.

the varieties of plant and animal life on the islands before writing *The Origin of Species* (1859). This book presented Darwin's theory of evolution (see **Darwin, Charles R.**).

Much of what is now Ecuador once made up part of the Inca Indian empire. Spanish conquerors overthrew the empire in 1534 and ruled the country for almost 300 years. Ecuador gained independence in 1830.

Government

Ecuador has had more than 15 constitutions since it gained independence from Spain. Most of these constitutions provided for an elected legislature, but in many elections few of Ecuador's people have been allowed to vote. Strong leaders have suspended or replaced many of the country's constitutions in order to stay in office or to increase their power. Most of Ecuador's rulers have been military leaders or have had the support of the armed forces.

But since 1979, the country has been governed by an elected government. Ecuador is a republic. The people elect a president to a four-year term. The president may not serve two terms in a row but may run again after spending a term out of office. The president appoints a 16-member Cabinet to help carry out the functions of government. An 82-member Chamber of Representatives is the country's lawmaking body. The people elect 12 of its members to four-year terms and 70 to two-year terms. Ecuador has 21 provinces. The president appoints a governor to each province except Pichincha Province, which does not have a governor. The Supreme Court is Ecuador's highest court.

Ecuador has many political parties. However, none of the political parties in the country has wide support among the people. The leading political parties in Ecuador include the Popular Democracy, the Roldosista Party, and the Social Christian Party. Many Ecuadorean leaders have organized their own political parties to win elections.

People

About 10 percent of Ecuador's people—mostly of European ancestry—make up the wealthiest and most powerful group in the country. Indians and *mestizos* (people of mixed Indian and white ancestry) each form about 40 percent of the population. Blacks, whose ancestors were brought to Ecuador as slaves of the Spaniards, make up the remaining 10 percent of the population. Most Ecuadoreans speak Spanish, and more than 90 percent of the population belongs to the Roman Catholic Church.

Way of life. Most of Ecuador's whites live in cities, and their lives resemble those of Europeans. Some of the whites in Quito and other Andean cities are absentee landowners who pay managers to run their *haciendas* (large farms or estates) for them. Most of the whites in Guayaquil and other coastal cities work in business or as traders. Some of the whites own large plantations that grow crops for export.

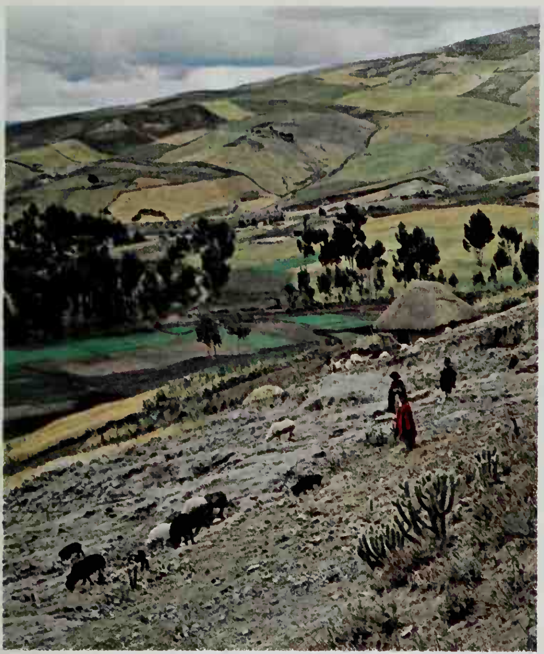
Most mestizos and blacks rank far below the whites in wealth and importance. Many mestizos live on the coastal plain in wooden homes with thatched roofs. Large numbers of the people work as day laborers on large banana or *cacao* plantations. Cacao is a seed used

The state flag, used by the government, bears the coat of arms. The people fly the national flag without the arms.

The coat of arms shows a condor, Chimborazo Mountain, and the first steamboat built in Ecuador.

WORLD BOOK map

Ecuador lies in western South America along the Pacific Ocean. It is bordered by Colombia and Peru.



Bjorn Bolstad, Photo Researchers

Ecuadorean shepherds tend a flock near a village on a rocky slope of the Andes. Most Andean villagers are Indians who make a bare living from farming and herding.

Stephanie Dinkins, Photo Researchers

Open-air regional markets sell foods and handicrafts produced in nearby villages. Villagers gather on market days to trade, meet friends, and celebrate with music and dancing.

in making chocolate and cocoa. Other people cultivate small plots of land that they have cleared in the forest. These farmers move from place to place as the soil wears out. Mestizo farmers in the Andes own land or work as day laborers on haciendas. Some mestizos live in the cities and work as laborers, servants, or shopkeepers. Most of the blacks in Ecuador live in the northern part of the coastal plain, and many of them fish for a living.

Many Indians of Ecuador have almost no power or money and little contact with the rest of the people. They speak Quechua or other Indian languages, wear Indian clothing, and follow Indian customs. Most of the Indians of Ecuador belong to the Roman Catholic Church, but their religion also includes many local beliefs and ceremonies.

Most of the Indians live in Andean villages. They build their houses of adobe for protection from the cold climate. Some of these Indians work on haciendas, growing crops and herding livestock. Many of them receive little or no pay. Instead, the landowner allows them to cultivate small plots of land on the hacienda and grow food for their families. Some Indian women weave cloth and make pottery. Many Indian children work with their parents. Some are shepherds in pastures high in the mountains.

Many Indian villages have their own special product or crop. The villagers carry these goods on their backs to regional markets and sell them. They hold *fiestas* (celebrations) at the end of market days and on religious holidays. Many villagers spend all their money on food and drink at these fiestas.

A few wandering tribespeople live in the eastern jungle and eat what they can find there. Missionaries have tried to bring economic help, education, and health care to these people.

Education and health. The Ecuadorean government requires all children from 6 to 14 years old to go to school. However, most of the schools are located in the cities and towns, and many rural children do not attend school. A majority of adult Ecuadoreans can read and write. For the country's literacy rate, see **Literacy** (table: Literacy rates for selected countries). Ecuador has 4 public universities, 3 private universities, and 10 technical schools.

The rural areas also have few hospitals or medical clinics. Many of the rural poor suffer from malnutrition and from an intestinal disease called *dysentery*. The Ecuadorean government is working to improve the people's health.

The land

The mainland of Ecuador has three regions: (1) the Coastal Lowland, (2) the Andes Highland, and (3) the Eastern Lowland. The Galapagos Islands also belong to Ecuador.

The Coastal Lowland is a flat plain along Ecuador's Pacific coast. It was formed by mud and sand carried down the mountains by rivers and deposited along the shore. The plain ranges from 12 to 100 miles (19 to 160 kilometers) wide and covers about a fourth of the country. In the north, the plain is wet and swampy. In the south, near Peru, it is a desert. In between, tropical forests cover much of the Coastal Lowland. The trees have

Carl Frank, Photo Researchers

Most highland farmers use primitive tools and farming methods. Many work for absentee landowners.

been cleared in some places, and the people farm the land. The Coastal Lowland has several rivers, including the Esmeraldas and the Guayas.

The Andes Highland, often called the *Sierra,* also makes up about a fourth of Ecuador. Two parallel ridges of the Andes Mountains extend the length of the country from north to south. A series of high plateaus lies between them. The mountain peaks rise over 20,000 feet (6,100 meters). Some of them are volcanoes, such as Cotopaxi in northern Ecuador. Reaching 19,347 feet (5,897 meters) high, it is one of the highest active volcanoes in the world.

The Eastern Lowland, often called the *Oriente,* covers almost half the country. The Eastern Lowland is a region of thick tropical forests in the eastern foothills of the Andes and in part of the Amazon River Basin. Many rivers, including the Napo and the Pastaza, flow through the Eastern Lowland. They make up part of the Amazon River system. Little of the region has been developed, and its people travel mostly by boat on the rivers.

The Galapagos Islands cover about 3,000 square miles (7,800 square kilometers) in the Pacific Ocean. Most of the islands are volcano peaks. Some rise 5,000 feet (1,500 meters). See **Galapagos Islands**.

Climate

Ecuador's climate varies according to the altitude. The Coastal Lowland and the Eastern Lowland are hot and humid. The Peru Current cools the Coastal Lowland slightly (see **Peru Current**). The temperature in the lowlands averages about 75 °F (24 °C). The tropical climate of the Galapagos Islands is cooled by the Peru Current.

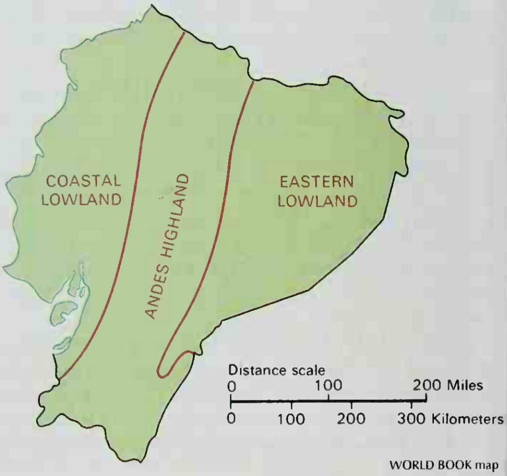
In the Andes Highland, the plateaus have springlike weather all year and an average temperature of 57 °F (14 °C). The climate is colder at higher altitudes. Snow covers the Andes from an altitude of about 16,000 feet (4,880 meters) up.

Feprotur

Ecuador's coast borders the Pacific Ocean. Rugged cliffs and sandy beaches line parts of the coast. A flat, fertile tropical plain lies farther inland.

Land regions of Ecuador

The map below shows the mainland regions of Ecuador—the Coastal Lowland, the Andes Highland, and the Eastern Lowland.



WORLD BOOK map

Provinces*

Azuay	562,725	E 4
Bolivar	168,034	C 4
Cañar	213,364	D 4
Carchi	150,778	A 5
Chimborazo	383,544	D 4
Colón (Galapagos Islands)	9,710	B 1
Cotopaxi	332,962	C 4
El Oro	464,709	E 3
Esmeraldas	335,229	A 3
Guayas	2,841,945	D 3
Imbabura	300,298	B 5
Loja	426,844	F 4
Los Ríos	591,550	D 4
Manabí	1,126,310	C 3
Morona-Santiago	99,365	D 5
Napo	192,109	C 5
Pastaza	44,476	C 5
Pichincha	1,984,743	B 4
Sucumbios†		B 6
Tungurahua	403,484	C 4
Zamora-Chinchipe	71,480	F 4

Cities

Ambato	137,418	C 4
Arenillas	13,522	E 3
Atuntaqui	15,572	B 5
Azogues	27,278	D 4
Babahoyo	62,974	D 4
Bahia de Caráquez	15,243	C 3
Balzar	27,246	C 3
Baños	12,092	C 5
Calceta	13,115	C 3
Cañar	15,372	D 4
Cariamanga	13,435	F 4
Catacocha	6,572	F 3
Catamayo*	14,903	F 4
Cayambe	19,145	B 5
Chone	50,496	C 3
Cotacachi	6,208	B 5
Cuenca	227,212	E 4
Daule	28,228	D 3
El Carmen	18,173	B 3
El Guabo*	11,020	E 3
Eloy Alfaro*	27,518	D 3
El Triunfo*	17,601	D 3
Esmeraldas	136,370	A 3
Flavio Alvaro*	6,975	B 3
Gualaceo	9,444	E 4
Guano	7,638	C 4
Guaranda	17,093	C 4
Guayaquil	1,764,170	D 3
Huaquillas*	34,459	E 3
Ibarra	74,186	B 5
Jipijapa	37,911	C 2
La Libertad*	56,795	D 2
La Maná*	9,069	C 4
Latacunga	39,598	C 4
La Troncal*	17,066	D 3
Loja	107,338	F 4
Macará	14,658	F 3
Macas	8,892	D 5
Machachi	8,805	B 4
Machala	166,270	E 3
Manta	155,757	C 2
Milagro	116,838	D 4
Montecristi	10,904	C 2
Naranjal	15,420	D 3
Naranjito*	15,311	D 3
Nueva Loja	14,580	B 6
Nueva Rocafuerte	8,240	C 3
Otavalo	24,196	B 5
Palestina*	6,059	C 3
Pasaje	35,507	E 3
Paján	7,812	C 3
Pedro Carbo*	16,995	D 3
Piñas	11,987	E 3
Playas	16,689	D 3
Portoviejo	163,898	C 3
Puerto Francisco de Orellana	7,845	B 6
Puyo	16,632	C 5
Quevedo	105,996	C 4
Quito	1,281,849	B 4
Riobamba	101,006	D 4
Rosa Zárate*	20,048	B 4
Salinas	27,831	D 2
Salitre*	7,336	D 3
Samborondón	10,010	D 3
San Gabriel	14,428	B 5
San Lorenzo	16,054	A 4
San Miguel de Salcedo*	8,042	C 4
Sangolquí	33,598	B 5
Santa Ana	7,718	C 3
Santa Elena	20,563	D 2
Santa Rosa	40,423	E 3
Santo Domingo*	127,028	B 4
Sucúa	6,181	C 5
Tena	8,558	C 5
Tosagua*	6,415	C 3
Tulcán	41,966	A 5
Velasco Ibarra*	27,518	C 3
Ventanas	26,818	C 3
Vinces	21,533	C 3
Yaguachi Nuevo	10,530	D 3
Zamora	9,141	F 4
Zaruma	6,885	E 4

Physical features

Aguarico River	B 7
Altar (mountain)	C 5
Antisana (volcano)	B 5
Baltra (island)	B 2
Bay of Manta	C 2
Bay of Santa Elena	D 2
Bay of Sardinas	C 3
Bobonaza River	D 6
Cape Pasado	B 3
Cape San Lorenzo	C 2
Catamayo River	F 3
Cayambe (volcano)	B 5
Cerros de Colonche (mountains)	D 3
Chimborazo (volcano)	C 4
Chinchipa River	F 4
Coca River	B 6
Cononaco River	C 6
Cordillera Cutucu Occidental (mountains)	D 3
Cordillera Occidental (mountains)	A 5
Cotopaxi (volcano)	C 4
Curaray River	C 6
Daule River	C 3
Esmeraldas River	A 4
Española (island)	B 2
Fernandina (island)	B 1
Galapagos Islands	B 1
Genovesa (island)	A 2
Guayas River	D 3
Gulf of Guayaquil	E 3
Isabela (island)	B 1
Marchena (island)	A 1
Mira River	A 5
Napo River	C 7
Pastaza River	D 6
Patul (mountain)	D 4
Pichincha (volcano)	B 4
Pindo River	D 6
Pinta (island)	A 7
Pinzón (island)	A 7
Point Saint Elena	D 2
Puná (island)	E 3
San Cristóbal (island)	B 2
San Miguel River	B 6
San Salvador (island)	A 1
Sangay (volcano)	D 5
Santa Clara (island)	E 3
Santa Cruz (island)	B 2
Santa Fe (island)	B 2
Santa Maria (island)	B 2
Santiago River	A 4
Sumaco (volcano)	C 5
Tiputini River	C 7
Vinces River	C 3
Zamora River	E 4

*Does not appear on map; key shows general location.
†Province was created in 1988; official population estimate not available.

Source: 1990 official estimates.

An average of 55 inches (140 centimeters) of rain falls in Ecuador every year. Heavy rainfall occurs in the Eastern Lowland and also in the northern part of the Coastal Lowland. The southern Coastal Lowland receives a light rainfall. Light rain also falls in the Galapagos Islands.

Economy

Service industries make up the largest part of Ecuador's *gross domestic product* (GDP)—the total value of goods and services produced each year. The country's service industries include communication and transportation, as well as finance, insurance, and real estate.

Petroleum is Ecuador's chief export. Other major exports include bananas, cocoa, coffee, and shrimp.

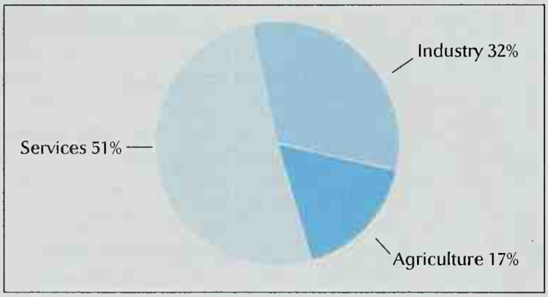
The United States is Ecuador's main trading partner for both exports and imports. Other nations with which Ecuador trades include Colombia, Germany, and Japan. Ecuador imports cars and trucks, chemicals, machinery, and many other products.

Manufacturing and mining. Most of Ecuador's manufacturing takes place in the Guayaquil and Quito areas.

Stephanie Dinkins, Photo Researchers

Panama hats, woven by hand, are a leading product of Ecuador. Although made in Ecuador, the hats are named for Panama, which became a shipping center for them in the 1800's.

Ecuador's gross domestic product



Ecuador's gross domestic product (GDP) was $19,768,000,000 in United States dollars in 1997. The GDP is the total value of goods and services produced within a country in a year. *Services* include community, government, and personal services; finance, insurance, real estate, and business services; transportation, communication, and utilities; and wholesale and retail trade. *Industry* includes construction, manufacturing, and mining. *Agriculture* includes agriculture, forestry, and fishing.

Production and workers by economic activities

Economic activities	Percent of GDP produced	Employed workers: Number of people	Employed workers: Percent of total
Agriculture, forestry, & fishing	17	1,035,700	32
Wholesale & retail trade	15	476,700	15
Manufacturing	15	370,300	12
Community, government, & personal services	14	838,100	26
Mining	14	20,900	1
Finance, insurance, real estate, & business services	12	81,400	3
Transportation, communication, & utilities	10	143,700	5
Construction	3	196,700	6
Total	100	3,163,500	100

GDP figures are for 1993, employment figures are for 1990.
Sources: International Monetary Fund; Ecuador National Institute of Statistics.

The nation's manufactured products include cement, drugs, Panama hats, processed foods, and textiles. The importance of mining to the nation's economy has increased greatly since Ecuador began exporting petroleum in the early 1970's.

Agriculture. Agriculture employs more people in Ecuador than does any other economic activity. Most of the nation's bananas, cacao, coffee, and sugar cane are raised on plantations in the Coastal Lowland. Oranges and rice are also grown in many coastal areas.

Most of the food for the people who live in Ecuador's cities comes from haciendas in the Andes Highland. Crops grown in the Andes Highland include beans, corn, potatoes, and wheat. Farmers raise cattle for meat and for dairy products.

Ecuador ranks as the world's leading producer of balsa wood, which grows in the Coastal Lowland. Forests in the Eastern Lowland yield such tropical hardwoods as mahogany. But much rich farmland and timberland in the Coastal and Eastern lowlands has not been developed.

The coastal waters of Ecuador are rich in fish. Ecuadoreans catch herring and mackerel along the coast. Shrimp are raised in ponds.

Transportation. The lack of all-weather roads between the Andes Highland and the Coastal and Eastern lowlands held back economic development in Ecuador for many years. New roads are helping Ecuador's people move from the thickly populated highland plateaus to the less crowded Coastal Lowland. The Pan American Highway runs through Ecuador from north to south, and a railroad connects Guayaquil, Quito, and San Lorenzo in the north. Less than 3 percent of Ecuador's people own an automobile. Quito and Guayaquil have international airports.

Communication. Ecuador has about 35 daily newspapers. The largest, *El Universo,* is a privately owned

newspaper published in Guayaquil. The country has an average of about 1 radio for every 3 people and 1 television set for every 12 people. Radio and television stations are privately owned. The government operates the telephone service. Ecuador has an average of about 3 telephones for every 100 people.

History

Indian period. During the late 1400's, Inca Indians from Peru conquered much of what is now Ecuador. At that time, many different tribes of Indians lived in Ecuador. In less than 50 years, the Inca united many of these tribes under a single government and taught the people the Inca language, Quechua. See **Inca**.

Spanish rule. In 1534, Spanish conquerors defeated the local rulers and took control of Ecuador. Most of the Spaniards settled in the Andes Highland. They made Quito their capital and built many beautiful churches and public buildings there. The Spaniards set up large haciendas and forced the Indians to work on them. Some Spaniards established plantations in the Coastal Lowland and imported black slaves to work on them. Many Spanish men married Indian women, and their children became the first mestizos of Ecuador.

The French emperor Napoleon invaded and conquered Spain in the early 1800's. The rulers of the Spanish colonies in Latin America took advantage of Spain's weakness to demand independence. In 1822, General Antonio José de Sucre defeated the Spaniards in the Battle of Pichincha near Quito and ended Spanish rule in Ecuador. Ecuador then joined in a confederation called *Gran Colombia,* which included what are now Colombia, Panama, and Venezuela. Eight years later, in 1830, Ecuador left the confederation and became an independent country.

Independence. Rival leaders fought for power in the new nation. Presidents, dictators, and *juntas* (groups of rulers) rose and fell. Most of the rulers ignored the rights and needs of the people.

In 1861, Gabriel García Moreno became president. García, a member of the Conservative Party, ruled with the support of the Roman Catholic Church and the landowners of the Andes Highland. During his rule, the government planned roads and railroads, developed agriculture and industry, and encouraged international trade. García was assassinated in 1875. Other Conservatives followed him in office, but none had enough power to continue his plans and policies.

In 1896, General Eloy Alfaro, a member of the Liberal Party, seized control of the government. The Liberals drew support from business executives in Guayaquil and from military leaders. They ended the power of the church over the government, finished the railroad connecting Quito and Guayaquil, and tried to modernize the government. But they did little to solve such basic social problems as the poverty of the Indians.

The 1900's. By 1925, the government's failure to solve Ecuador's economic and social problems had led to widespread dissatisfaction. Many political groups were formed, and Ecuador had 22 presidents or chiefs of state from 1925 to 1948. None of these leaders served a complete term.

A border dispute between Ecuador and Peru led to war in 1941. That year, Peru seized territory in the Amazon Basin that Ecuador had claimed. Latin American leaders met in Rio de Janeiro, Brazil, and worked out a settlement that gave most of the disputed territory to Peru. But Ecuador still claimed the land, and fighting broke out between the two countries several times. In 1998, Ecuador and Peru signed a treaty that established the border between them and ended the dispute.

Ecuador had political calm and progress from 1948 to 1960. More and more people were permitted to vote, and they elected presidents who served full terms. All these presidents worked for economic development and a fairer distribution of land and wealth.

Galo Plaza Lasso, a Liberal Party candidate, won election to the presidency in 1948 and served until 1952. José María Velasco Ibarra, a political independent, followed him. Velasco claimed a special interest in helping the poor, and he was widely popular. Camilo Ponce Enríquez, the candidate of the Conservative Party, became president in 1956 and served until 1960.

In 1960, Velasco won another term as president. But he was forced out of office after trying to levy new taxes. Vice President Carlos Julio Arosemena Monroy replaced him. In 1963, the armed forces overthrew Arosemena and suspended the Constitution. They said they acted to prevent a Communist take-over. A military junta began to make land and tax reforms. But the people demanded an end to military rule.

In 1966, military leaders named Clemente Yerovi Inda-

© A. Upitis, FPG

Bananas, one of Ecuador's most important crops, are grown on plantations in the Coastal Lowland. They are packed in boxes and loaded on ships at Guayaquil, the country's chief port. Ecuador is a leading exporter of bananas.

buru to be temporary civilian president. Yerovi called a constitutional convention. The convention wrote a new Constitution and chose Otto Arosemena Gómez to serve as president until an election could be held. Velasco was elected president once again in 1968. In 1970, he suspended Ecuador's Constitution and began to govern as a dictator. Military leaders overthrew Velasco in 1972, and General Guillermo Rodríguez Lara took power. In 1976, the commanders of Ecuador's army, navy, and air force removed Rodríguez Lara from office and took control of the country's government.

In 1979, elections were held to establish a new civilian government. Elections were then held regularly. In 1997, however, Ecuador's legislature removed President Abdalá Bucaram Ortiz from office and appointed an interim president, Fabián Alarcón. In 1998, voters elected Jamil Mahuad president.

Ecuador faced a severe economic crisis in 1999 and early 2000. The nation failed to pay back loans from several international lending organizations, and its currency dropped sharply in value. In January 2000, a coalition of military officers and Indian groups forced Mahuad from office. Vice President Gustavo Noboa Bejarano took over as president. In March, the government adopted economic reforms, including a plan to make the U.S. dollar the official currency of Ecuador. Murdo J. MacLeod

Related articles in *World Book* include:

Andes Mountains	Food (picture: Indians of Ecuador)	Jívaro Indians
Balsa	Galapagos Islands	Latin America
Chimborazo	Guayaquil	Pichincha
Clothing (pictures)	Inca	Quito
Cotopaxi		Sucre, Antonio
Cuenca		

Outline

I. Government
II. People
A. Way of life
B. Education and health
III. The land
A. The Coastal Lowland
B. The Andes Highland
C. The Eastern Lowland
D. The Galapagos Islands
IV. Climate
V. Economy
A. Manufacturing and mining
B. Agriculture
C. Transportation
D. Communication
VI. History

Questions

What does the word *ecuador* mean?
What countries border Ecuador?
What is Ecuador's most important economic activity?
What part of Ecuador is growing fastest? Why?
What is Ecuador's main seaport?
What are the chief exports of Ecuador?
Who ruled Ecuador before it gained independence?
What country controls land claimed by Ecuador?
What nation is Ecuador's chief trading partner?
What are the Galapagos Islands known for?

Additional resources

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Insight Guide editors. *Insight Guide to Ecuador.* Rev. ed. Houghton, 1995.
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Schodt, David W. *Ecuador.* Westview, 1987.

Ecumenical council. See Vatican Council I; Vatican Council II.

Eczema, *EHK suh muh* or *ehg ZEE muh,* is a skin disorder characterized by itching and inflammation. The inflamed skin may be dry, swollen, and crusty, or it may ooze fluids. There are several forms of eczema, none of which is contagious. Common types include *atopic eczema, neurodermatitis,* and *contact dermatitis.*

Atopic eczema, also called *atopic dermatitis,* tends to run in families. Most cases begin during infancy and are outgrown by 3 or 4 years of age. Some continue through adulthood, flaring up occasionally—especially when the victim is upset, angry, or worried. Treatment includes the use of lotions or ointments, some of which may contain drugs called *corticosteroids.*

Neurodermatitis forms thickened patches on the skin, particularly on the back of the neck or on an ankle. In most cases, people develop the condition by scratching an area repeatedly when they are nervous. Scratching damages the skin and makes it itch even more, which leads to more scratching. Treatment involves eliminating the habit of nervous scratching.

Contact dermatitis is an allergic reaction to certain substances a person touches. Poison ivy or poison oak, for example, causes this type of eczema wherever the plant touches the skin. Treatment of contact dermatitis includes avoiding further contact with the substances that cause the reaction. Yelva Liptzin Lynfield

Edda, *EHD uh,* is a term that refers to two separate works of medieval Icelandic literature. The *Poetic,* or *Elder, Edda* is a collection of anonymous poems composed in the 1000's and 1100's. The *Prose,* or *Younger, Edda* is a textbook for poets that was written during the 1200's by the Icelandic poet and historian Snorri Sturluson. His work was the first to be called *Edda,* a name that may be related to an Icelandic word meaning *song* or *poem.* Later, the term was applied to the *Elder Edda,* too.

Twenty-four of the 38 poems in the *Poetic Edda* are heroic tales, many of them concerned with the exploits of the hero Sigurd (Siegfried in German). The remaining 14 poems contain mythological material, including accounts of the creation and end of the universe. The longest of these poems is *The Sayings of the High One.* It contains practical wisdom and reveals the moral attitudes of the people of medieval Scandinavia.

Snorri's *Prose Edda* consists of a preface and three sections. The first section narrates myths about Scandinavian deities. The second explores features of poetic diction and exemplifies their use by narrating additional myths. The final section is a poem of 102 verses, each illustrating a type of meter or stanza form. Richard N. Ringler

See also Sigurd; Snorri Sturluson; Skald; Mythology (Teutonic mythology).

Eddington, Sir Arthur Stanley (1882-1944), was a British astronomer who pioneered in the investigation of the internal structure of stars. Eddington wondered what prevents a star from collapsing inward under its own gravitational pressure. In 1926, he showed that enough outward pressure is produced by the light and other electromagnetic radiation inside the star, and by the gas of which the star is composed.

Eddington led the campaign in the United Kingdom for acceptance of the *theory of general relativity,* a set of ideas proposed by German-born physicist Albert Einstein. The theory deals with the physical laws that govern time, space, mass, motion, and gravitation. During a

solar eclipse in 1919, Eddington's observation team detected the bending aside of starlight by the sun's gravitational field. Their observation supported Einstein's theory, which had predicted that effect. In 1924, Eddington showed a fundamental relationship between the mass and brightness of a star. In most cases, the more mass a star has, the brighter it is.

Eddington was born at Kendal, England. He studied at Manchester and Cambridge universities and directed the Cambridge University Observatory from 1914 to 1944. Karl Hufbauer

See also **Sun** (Core).

Eddy, Mary Baker (1821-1910), was an American religious thinker and leader. She founded the Christian Science denomination—the Church of Christ, Scientist—in 1879. She developed a theology of spiritual healing, which remains controversial but continues to influence Christianity. See **Christian Scientists.**

Eddy, whose maiden name was Mary Morse Baker, was born on a farm in Bow, New Hampshire. In her youth, she rebelled against the New England Puritan idea of a harsh and unforgiving God. But her religious upbringing also gave her a deep love of the Bible.

Eddy's personal misfortunes increased her religious questioning. In 1844, her first husband died after less than a year of marriage. She married Daniel Patterson in 1853. During much of this time, she was in poor health, and she began to investigate methods of healing. In 1862, she met Phineas Quimby, who claimed to relieve people of their ailments through what today would be called the power of suggestion. Her contact with Quimby reinforced her own growing conviction that disease had a mental, rather than a physical, cause. But Eddy eventually broke with Quimby, insisting that true healing came from God's power acting on, not through, the human mind.


The Christian Science Publishing Society
Mary Baker Eddy

Eddy gained this conviction in 1866, when she recovered from an injury while reading about one of Jesus's healings in the Gospels. For the next nine years, she studied the Bible, practiced and taught healing, and wrote. In 1875, she published the "textbook" of Christian Science, ultimately named *Science and Health with Key to the Scriptures.* In it, she stated that disease and other evils result from the human mind's ignorance of our relationship to God. She taught that through Christian discipleship, people can follow Jesus's command that His followers practice spiritual healing. Eddy saw Jesus's healing works and Resurrection as demonstrating that the true nature of reality is spiritual, not bound by material limits.

Eddy devoted the rest of her life to advancing what she saw as her discovery of the "science," or underlying spiritual laws, that explain Biblical events and show their continuing meaning. Eddy's second marriage ended in divorce in 1873, and she married Asa G. Eddy in 1877.

In 1892, she reorganized the Christian Science church into its present form. In 1908, she founded the daily newspaper *The Christian Science Monitor* as a crucial link between her church and the world.

Stephen Gottschalk

Additional resources

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Thomas, Robert D. *"With Bleeding Footsteps": Mary Baker Eddy's Path to Religious Leadership.* Knopf, 1994.

Edelweiss, *AY duhl vys* or *AY duhl wys,* is a flower that grows in the mountain regions of Europe and Asia. The edelweiss has long, narrow leaves and grows from 4 to 12 inches (10 to 30 centimeters) tall. White, star-shaped flowers grow from the leaves.

The edelweiss can be cultivated in cool regions of America and Europe. In its native countries the edelweiss is considered a rare plant, because it grows wild in high regions and is difficult to obtain. James S. Miller


WORLD BOOK illustration by Christabel King
Edelweiss

Scientific classification. The edelweiss belongs to the composite family, Compositae. It is *Leontopodium alpinum.*

Edema, *ih DEE muh,* is swelling of body tissues caused by fluid build-up between cells. Cells are bathed and nourished by fluid that always seeps from *capillaries,* the tiniest blood vessels. Normally, the seepage is balanced by reabsorption of fluid into the capillaries and by drainage into the *lymphatic system* (see **Lymphatic system**). When this balance is upset, edema results.

Edema may be *local*—that is, limited to one part of the body—or it may be general, affecting tissues throughout the body. Local edema commonly results when injured capillaries leak their contents into nearby tissue spaces. Such local edema is corrected by treating the injury and by elevating the affected body part.

The most common cause of general edema is heart failure. When a weak heart does not circulate the blood effectively, the kidneys cannot remove enough water and salt from the bloodstream. As a result, the blood volume increases, and excess liquid seeps into the body tissues, particularly the legs and lungs. The condition is called *pulmonary edema* when excess fluid accumulates in the lungs, causing shortness of breath. Physicians treat edema due to heart failure with drugs or surgery to improve heart function. Patients also receive *diuretics,* medicines that increase the amount of water and salt eliminated by the kidneys.

General edema also often results if poor diet, liver disease, or kidney disease causes a drop in the blood plasma's protein content. Proteins in blood plasma play a major role in the blood's ability to retain fluid. High-protein diets help correct this type of edema.

Problems with lymphatic drainage cause *lymphedema.* This condition often requires long periods of bed

rest, with the affected body parts elevated and tightly wrapped to reduce swelling. The most dramatic form of lymphedema is *elephantiasis,* a disease in which parts of the body swell and the skin becomes rough and thickened like that of an elephant. Giacomo A. DeLaria

See also **Diuretic; Elephantiasis.**

Eden, *EE duhn,* was a region described in the Bible as the place where God planted a garden for Adam and Eve. The name comes from a Sumerian word that means *plain.* Chapter 2 of Genesis tells that the garden contained beautiful fruit-bearing trees, and the tree of life and the tree of the knowledge of good and evil. A stream flowed from the garden and divided into four rivers. Two of these are thought to be the Tigris and Euphrates rivers. The other two, called Pishon and Gihon, have not been identified. The four rivers may represent an ancient belief in four great streams that surrounded the world. See also **Adam and Eve.** H. Darrell Lance

Eden, Sir Anthony (1897-1977), Earl of Avon, succeeded Sir Winston Churchill as prime minister of the United Kingdom from 1955 to 1957. He was the leader of the British Conservative Party during that time. Eden was largely responsible for the United Kingdom's decision to join France in attempting to seize the Suez Canal in October 1956 after Egypt had *nationalized* (taken control of) it in July. He was criticized greatly for this. Under United Nations pressure, a cease-fire was quickly arranged (see **Suez Canal** [History]). Eden resigned in January 1957.

Eden was born on June 12, 1897, in Durham, England. In World War I (1914-1918), he fought in France and was awarded the Military Cross for distinguished service. He graduated from Oxford University in 1922. Eden entered Parliament in 1923. He became the United Kingdom's foreign secretary in 1935 but resigned in 1938 because Prime Minister Neville Chamberlain yielded to the demands of dictators Adolf Hitler of Germany and Benito Mussolini of Italy. He again served as foreign secretary from 1940 to 1945 and from 1951 to 1955. He received the title Earl of Avon in 1961. Keith Robbins

Edentate, *ee DEHN tayt,* is any one of a group of mammals that have incomplete sets of teeth or no teeth at all. Anteaters, armadillos, and sloths are the only living edentates. These animals are most common in South America, but they are also found in Central America and parts of North America. The armadillo is the only edentate that lives in the United States. Edentate means *toothless,* but armadillos and sloths have back teeth. Some edentates have a hard, bony covering. Others are covered only by hair. Bruce A. Brewer

Scientific classification. Edentates make up the order Xenarthra in the class Mammalia.

See also **Anteater; Armadillo; Ground sloth; Sloth.**

Ederle, *AY duhr lee,* **Gertrude Caroline** (1906-), a famous American swimmer, became the first woman to swim the English Channel. In 1926, at the age of 19, Ederle swam the channel from France to England. Her time of 14 hours 39 minutes for the 35-mile (56-kilometer) distance broke the previous record and stood as the women's record for 35 years.

From 1921 to 1925, Ederle set 29 United States and world records for races ranging from the 50-yard to the half-mile race. In the 1924 Summer Olympic Games, she won a gold medal as a member of the championship U.S. 400-meter freestyle relay team. She also won bronze medals for finishing third in the 100-meter and 400-meter freestyle races. Ederle was born on Oct. 23, 1906, in New York City.

William F. Reed

Brown Brothers

Gertrude Ederle

Edgerton, Harold Eugene (1903-1990), an American engineer and inventor, revolutionized high-speed photography with his *electronic stroboscope,* an instrument that can produce single or rapidly repeating flashes of light. Edgerton used this device to produce famous stop-action photographs of such subjects as a bullet tearing through a playing card. See **Ballistics.**

Edgerton also used the stroboscope in motion-picture photography, enabling him to show high-speed processes in slow motion. This technique was used in the film short *Quicker 'n a Wink,* which won an Academy Award in 1940. His other inventions include the first electronic flash equipment used to take aerial photographs at night, deep-sea cameras, and sonar systems. See **Sonar.**

Edgerton was born on April 6, 1903, in Fremont, Nebraska. He received a Doctor of Science degree from Massachusetts Institute of Technology (MIT) in 1931. He became an assistant professor at MIT in 1932 and remained at MIT until his death. J. Kim Vandiver

Edict of Nantes. See Nantes, Edict of.

Edinburgh, *EH duhn buh ruh* (pop. 421,213), is the capital and second largest city of Scotland. Glasgow is Scotland's largest city. Edinburgh stands on the hills south of the Firth of Forth. The original name of the city was *Dineiden,* which meant "fortress on a hill." For the

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Edinburgh Castle stands on a huge rock overlooking the city. Pipers in kilts lead frequent parades past the castle gates.

location of Edinburgh, see **Scotland** (political map).

The city's main thoroughfare, Princes Street, lies at the south edge of Edinburgh's New Town area. This area, which was built during the late 1700's and the early 1800's, was laid out in a symmetrical pattern. Many of Scotland's great buildings stand along the north side of Princes Street. Railroad trains pass through a small valley along the south side of the street. Princes Street Gardens, which are famous for their flower clock, are in the valley.

South of the valley, Edinburgh Castle stands atop Castle Rock. Within the castle walls is the Norman Chapel of Saint Margaret. This chapel was probably built during the 1000's. Along the Royal Mile, which leads from the castle to the Palace of Holyroodhouse, stand historic houses and Saint Giles's Cathedral.

Edinburgh has long been important as a cultural and educational center. The University of Edinburgh and the Royal High School were founded in the 1500's. The Advocates' Library, where the philosopher David Hume was once librarian, was founded in 1682. Major art collections are housed in the Royal Scottish Academy, the Royal Scottish Museum, and the National Gallery of Scotland. The annual Edinburgh International Festival of the Arts, a festival of musical and dramatic productions, attracts exhibitors from many countries.

Edinburgh publishers have sponsored well-known magazines, including the *Edinburgh Review* and *Chambers Edinburgh Journal.* Many leading Scottish authors, and John Knox—who led the Protestant Reformation in Scotland—lived in Edinburgh.

Industries in Edinburgh include breweries and distilleries, and paper and textile mills. The city is also a banking and insurance center. A. S. Mather

For the monthly weather in Edinburgh, see **United Kingdom** (Climate). See also **Scotland** (picture).

Edinburgh, Duke of. See Philip, Prince.

Edinburgh, *EH duhn buh roh,* **University of,** is one of the oldest and best-known universities in the United Kingdom. The university was founded in Edinburgh, Scotland, in 1583. The school has *faculties* (divisions) of arts, divinity, law, medicine, music, science, social sciences, and veterinary medicine. P. A. McGinley

Edirne, *eh DIHR neh,* formerly Adrianople, *AY dree uh NOH puhl* (pop. 102,300), is an ancient Turkish city. It was the European capital of the Ottoman Empire from 1361 until the Ottomans captured Constantinople in 1453. Edirne is in northwestern Turkey, near the Bulgarian border where the Maritsa, Arda, and Tunca rivers meet (see **Turkey** [political map]). Edirne was once a great trading center. Today it is still an important regional trading city in Turkey. The mosque of Selim II, built in the 1500's, stands in Edirne. It is considered the masterpiece of the great Turkish architect Koca Sinan.

The Roman emperor Hadrian founded the city on the ruins of an ancient Thracian city and named it Hadrianopolis. Several major battles took place near the city, among them the defeat of Roman troops by Visigoths in A.D. 378. The Ottomans took over the city in 1360. Russian troops captured it in 1829 and 1878. Bulgarians briefly occupied the city in 1913 during the Balkan Wars. Edirne became a part of the new Republic of Turkey in 1923, the year after the Ottoman Empire was abolished.

F. Muge Gocek

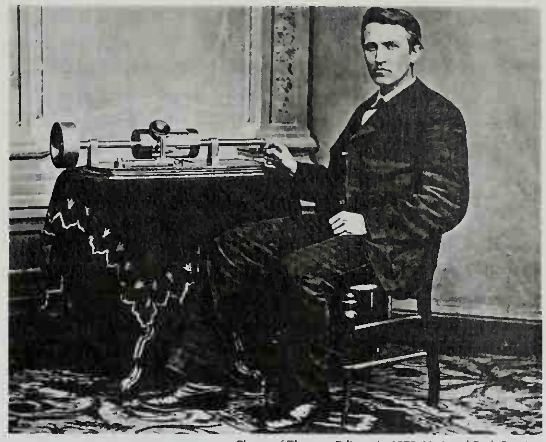

Photo of Thomas Edison in 1878; National Park Service

Edison's phonograph, perhaps his favorite invention, played sounds recorded on a cylinder covered with tinfoil.

Thomas Alva Edison

Edison, Thomas Alva (1847-1931), was one of the greatest inventors and industrial leaders in history. His most famous contributions include practical electric lighting, the phonograph, and improvements to the telegraph, telephone, and motion pictures. Edison also created one of the first modern research laboratories. Some scientists and historians regard his development of the research lab as his greatest achievement.

Edison looked for many different solutions when attempting to solve problems. When he created new or improved devices, he made a variety of designs. Sometimes he borrowed features from one technology and adapted them to another. Edison obtained 1,093 United States patents, the most the U.S. patent office has ever issued to one person. Altogether, he received thousands of patents from some two dozen nations.

Edison's promotion of the research laboratory grew out of his methods of work. He usually worked alongside his assistants. He wanted to see how others had solved mechanical, electrical, and chemical problems and then tried to improve upon their ideas. Early in his career, Edison hired machine shop assistants to help him. Within a few years, he established a laboratory for inventing. By the early 1900's, U.S. corporations had seen the success of research labs, such as Edison's and those in Germany, and began establishing their own.

Edison was also a good businessman. He not only loved to design new devices but also wanted them to be used by many people. He found financial partners worldwide and created new companies to manufacture and sell his products. Income from selling his products helped support his research laboratory and the development of more devices. As a result, Edison and other manufacturing pioneers in the late 1800's helped make the United States an industrial world power.

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Armed with self-confidence and determination, Edison overcame a number of technical and commercial failures. He became world famous by his mid-30's and a millionaire by his mid-40's. Today, Edison's name and electric light bulb are worldwide symbols of bright ideas and technical creativity.

Early life

Boyhood. Edison was born on Feb. 11, 1847, in Milan, Ohio. He was the seventh and youngest child of Samuel and Nancy Elliott Edison. Edison's father fled from Canada during the Rebellions of 1837 and worked in Milan as a shingle maker and land investor. When Al—as the family called the young Edison—was 7 years old, the Edisons moved to Port Huron, Mich. There his father ran businesses in lumbering and land investing.

National Park Service, Edison National Historic Site

Edison at age 14

Edison received limited formal education. His mother, a former teacher, guided his learning. Edison was mischievous and inquisitive. He loved to pull pranks and practical jokes. He was also eager to read, particularly science books. His reading led him to experiment with chemicals and to construct elaborate models. He built models of a working sawmill and a railroad engine, both of which were powered by steam.

Even as a child, Edison was venturesome in business. He grew vegetables on his father's farm and sold them in town. At age 12, Edison began to sell newspapers, candy, and sandwiches on passenger trains between Port Huron and Detroit. Later, he hired others to work for him selling goods on the train and at stops. When he was 15, he published and sold a newspaper called the *Weekly Herald.* By this time, Edison had also developed hearing problems. His condition worsened as he grew older, and late in life he could only hear people if they shouted directly into his ear.

Edison Birthplace Museum

Edison's birthplace was this red brick house in Milan, Ohio. Edison lived in Milan until he moved with his family to Port Huron, Mich., when he was 7 years old.

The young telegrapher. At age 15, Edison rescued the son of a telegraph operator from the path of a railroad car. As a reward, the operator gave Edison telegraph lessons. In 1863, Edison began work as a telegraph operator for the Western Union Telegraph Company in Port Huron. During the following four years, he worked as a telegrapher in a number of Midwestern cities. Edison learned much about the mechanical, electrical, and chemical elements of telegraphy. He read scientific and telegraph journals and books, and experimented with telegraph equipment.

Despite Edison's hearing difficulties, he mastered the art of receiving news reports by telegraph. He used a skill common among hearing-impaired people called "filling the gaps," or guessing. Many telegraph operators used this skill to finish interrupted and incomplete messages. Edison used it even more. He read newspapers in his spare time to gather information that might help him complete messages. As a telegraph operator, Edison learned of news and information that helped him develop a keen awareness of political and business matters throughout the nation.

Inventor and businessman

Telegraph innovator. In 1868, Edison moved to Boston as a telegraph operator. While in Boston, he made improvements on a town fire alarm system, on printing telegraphs for stockbrokers, and on a device to transmit images over telegraph lines. Edison also applied for his first patent. But the invention, an electrical vote-recorder for legislatures, was never used.

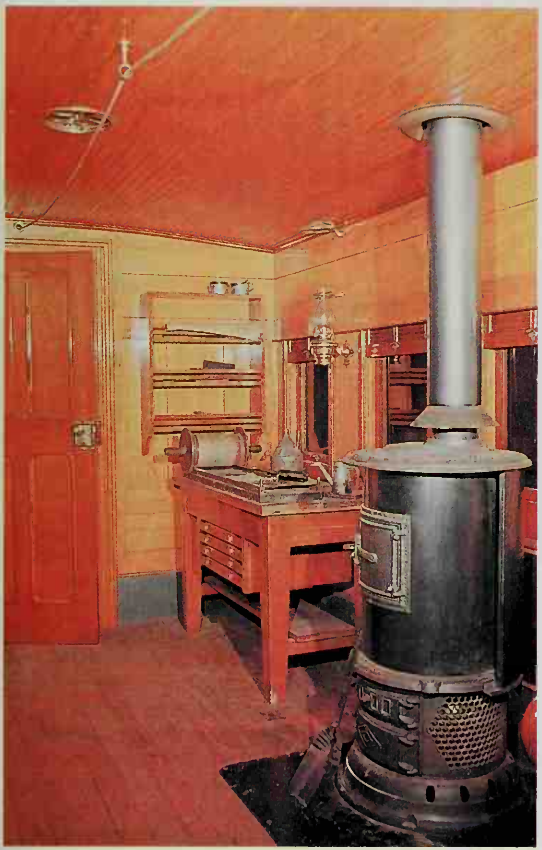
In 1869, Edison moved to New York City. There he met the leaders of the telegraph industry and important people in the financial community. He also developed improvements in *stock tickers,* telegraph devices used to report the purchase and sale of stocks.

In 1870, Edison moved to Newark, N.J. In partnership with a machine shop operator, he started a stock ticker manufacturing company. To keep the business successful, Edison continually tried to improve the devices he sold. Charles Batchelor and other mechanically talented associates joined the new manufacturer in developing a steady stream of inventions.

In 1874, Edison completed the design of the *quadruplex.* This improved telegraph was faster and more efficient than the regular telegraph. The quadruplex could send four messages at a time on a single wire instead of just one message. This important invention strengthened Edison's reputation as an inventor in the telegraph community.

The Wizard of Menlo Park. In the spring of 1876, Edison built a laboratory in rural Menlo Park, about 25 miles (40 kilometers) south of Newark. With financial support from Western Union, Edison and his assistants began research that transformed the world.

Telephone transmitter. Edison was one of many inventors who tinkered with the "speaking telegraph," as the telephone was then called. Alexander Graham Bell patented the telephone in 1876. In 1877, Edison designed a superior transmitter, which made a speaker's voice louder and clearer on the telephone. For the next century, most phones used transmitters based on Edison's improvement. Before his invention, people had difficulty hearing anything said over the telephone.



Brent Groth

Edison's baggage-car laboratory, shown in this restoration, was part of the train on which he worked when he was 12. Young Edison conducted chemical experiments in this car.

The phonograph. In 1876 and 1877, Edison worked on important experiments for recording and playing back messages sent over the telegraph and telephone. These experiments led to his invention of the cylinder phonograph. To record messages, Edison attached a needle to a *diaphragm,* a metal disk that vibrated in response to the sound waves of a voice. The needle rested against a rotating cylinder that was wrapped with tinfoil. When the disk vibrated, the needle made varying impressions in the foil. To reproduce the sound, another needle was attached to a diaphragm and funnellike horn. This needle retraced the impressions or grooves in the foil. While developing the cylinder phonograph, Edison also made designs for recording sound on disks and tapes.

In December 1877, Edison exhibited his cylinder phonograph to the editors of the prominent magazine *Scientific American.* The next spring, he demonstrated it to scientific societies and at the White House for U.S. President Rutherford B. Hayes. The device seemed like magic—nothing like it had ever been invented. As a result, Edison became world famous as the Wizard of Menlo Park.

However, the invention was so unusual that at first no one knew what to do with it. Edison envisioned the phonograph being used as a dictating machine. But he also sought other uses. He designed toys that would use the device, including talking dolls and children's pianos. Later, other people introduced the idea of selling musical recordings for the phonograph, and soon Edison began making his own recordings.

The electric light. In 1878, Edison began important research on electric lighting. Inventors worldwide also were investigating the process. In September, Edison saw a demonstration of a carbon arc light. This device produced an extremely bright light by sending electricity across a gap between two carbon terminals.

Edison then began work on an *incandescent* lamp for use in homes. An incandescent lamp would produce a less intense light by passing electricity through a *filament* (wire) to make the filament glow. Edison and his associates spent months searching for the filament material that would produce the best light. In October 1879, they successfully tested a carbon filament made from burned sewing thread, producing the first practical incandescent light bulb. In 1880, they began using bamboo filaments, which increased the life of the bulbs.

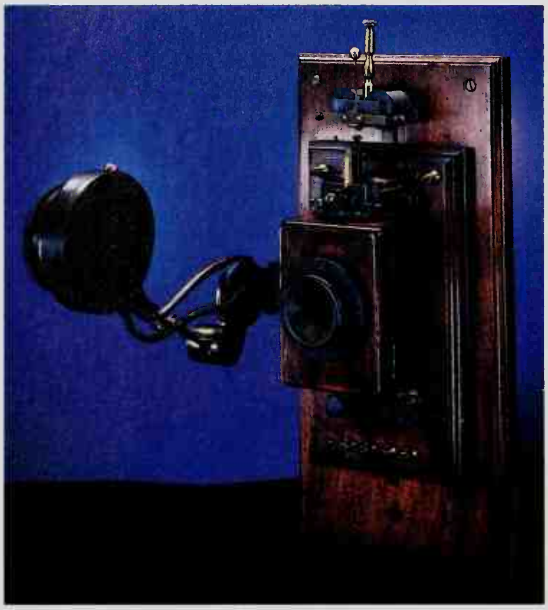
At first, Edison's electric light was only a novelty because few homes and businesses had electricity. To make his invention practical for everyday use, electricity had to be readily available to customers. He began working to produce electricity in central power plants and distribute it over wires to businesses and homes.

Electric utilities and electrical manufacturing. In 1881, Edison and his associates moved to New York City to promote the construction of electric power plants in cities. Edison built the Pearl Street Station, a steam electric power plant near Wall Street. The station opened in 1882 and soon provided electricity to many customers. By the 1890's, hundreds of communities throughout the world had Edison power stations.

To make the electric lighting system commercially successful, other equipment also had to be readily available, such as generators, power cables, electric lamps, and lighting fixtures. Thus, Edison and some of his associates invested in companies that manufactured these products. These companies combined with others to become the General Electric Company in 1892.

National Park Service, Edison National Historic Site

A printing telegraph for stockbrokers was one of Edison's first inventions and one of many he made in telegraphy.



From the collections of the Henry Ford Museum and Greenfield Village

A telephone from the late 1800's was one of many that used Edison's transmitter, which made the speaker's voice louder.

Inventor-industrialist of West Orange. In 1886, Edison moved to Llewellyn Park, a residential area of West Orange, N.J. Just blocks away, he built a laboratory 10 times the size of the one in Menlo Park. The new lab included a three-story office that housed thousands of journals and books. The lab also provided space for chemical, mechanical, and electrical experiments. Eventually, it included facilities for manufacturing the devices designed by Edison and his associates. For the remaining years of Edison's life, this lab was his true home.

Motion pictures. Edison helped found the motion-picture industry. In early 1888, he met British-born photographer Eadweard Muybridge. One of many people experimenting with photography of motion, Muybridge inspired Edison to investigate the field. By fall, Edison envisioned a motion-picture device that looked like the cylinder phonograph. He wrote, "I am experimenting upon an instrument which does for the Eye what the phonograph does for the Ear."

Edison and his lab photographer, W. K. L. Dickson, began to record a series of images on celluloid film. Showing the images in rapid succession would make them look like continuous action. Over the next five years, Edison and his assistants invented the peephole *kinetoscope.* The kinetoscope was the first practical motion-picture device that used a roll of film. It consisted of a cabinet with a peephole or eyepiece on top. A customer who put a coin in the machine could watch a short motion picture through the hole. In 1893, Dickson built the Black Maria, Edison's film studio. The Black Maria was the first building designed for the purpose of making commercial motion pictures.

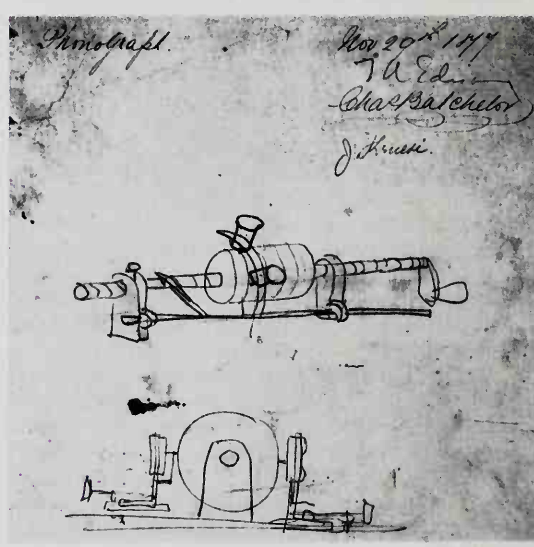
From the mid-1890's to about 1915, Edison tried to control the motion-picture industry in the United States. In 1896, his company introduced projectors designed by other inventors. It soon became a principal producer and distributor of motion pictures. In 1908, Edison and most other movie inventors pooled their patents. Together they formed the Motion Picture Patents Company, which largely controlled the production, distribution, and exhibition of motion pictures. But in 1917, the Supreme Court of the United States upheld a ruling that the company was an illegal monopoly. As a result, Edison and most other members of the Motion Picture Patents Company lost much of their influence in filmmaking. Many of them abandoned the industry that Edison had helped found.

Ore milling. In the late 1800's, Edison designed gigantic equipment to process low-grade iron ore into high-grade ore for steel mills in the Eastern United States. He established a processing plant in northern New Jersey in the early 1890's. At the plant, raw ore moved continuously on conveyor belts in a system like the assembly line later popularized by American automaker Henry Ford.

Edison invested more than $1 million in ore milling. His advanced technology was successful, but the project still ended in failure. It failed largely because rich iron ore discovered in the Mesabi Range of northeastern Minnesota was less expensive to mine and process.

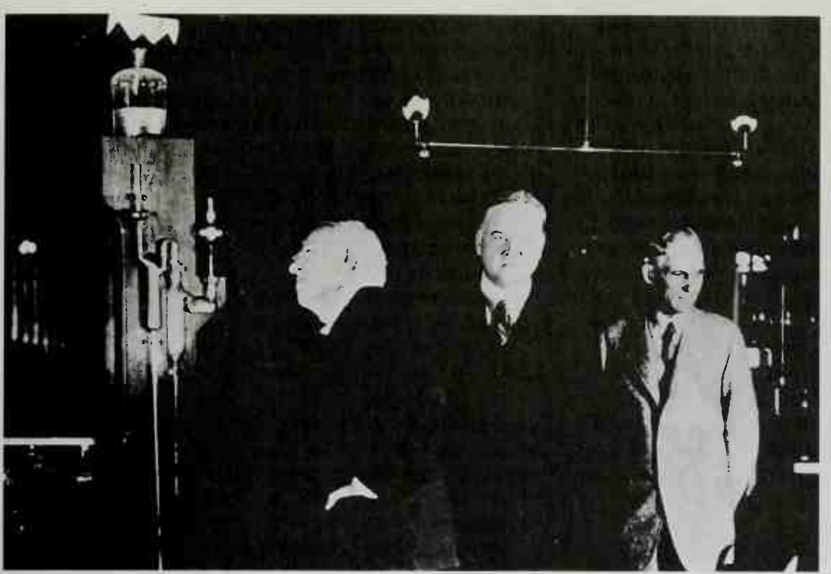
Primary and storage batteries. During the 1880's and 1890's, Edison and his associates had experimented with batteries. They worked on designing and producing lighter, more durable, and more powerful batteries. By the early 1900's, one of Edison's companies began to manufacture batteries. Railroads used his batteries to power signals and switches. Edison batteries also were used in electric automobiles and for electric starters in gasoline-powered cars.

Cement manufacture. In the early 1900's, one of Edison's companies began mass-producing portland cement, a gray powder used to make concrete. Edison had built one of the largest cement plants in the United States in western New Jersey. The plant used some



National Park Service, Edison National Historic Site

A page from Edison's sketchbooks, *above,* shows a front and a side view of his cylinder phonograph. The sketchbooks include drawings and notes on his inventions and experiments.



Henry Ford Museum

Edison's first incandescent electric light, *below,* was perhaps his most important invention. Edison, *far left,* President Herbert Hoover, and Henry Ford inspected the device in 1929 in a reconstruction of Edison's Menlo Park laboratory at Greenfield Village in Dearborn, Mich.

Museum of Science and Industry, Chicago (WORLD BOOK photo by Chris Stanley)

equipment from his failed ore project. To help make the works profitable, Edison searched for new uses of cement. He introduced poured concrete houses. He sold cement for use in large factories and for building Yankee Stadium and other structures in New York City. He even designed concrete furniture.

Phonograph developments. Also at West Orange, Edison improved and sold his favorite invention, the phonograph. He and his associates investigated materials on which to make recordings. He then produced chemicals to manufacture the recording materials.

Cylinder phonographs, such as Edison's, were mechanically and acoustically better than disk phonographs. But disk records were easier to produce and store than cylinder recordings. Reluctantly, Edison switched to the disk format in 1913. However, he continued to develop and later sold the *Ediphone,* a dictating machine based on his cylinder phonograph.

Last work. During World War I (1914-1918), Edison headed the Naval Consulting Board of the United States, a group of inventors and business people who aided the war effort. After the war, Edison returned to his experiments at the laboratory. But he turned over most of the administrative work to his son Charles.

In the late 1920's, Edison sought a substitute for rubber plants as a source of latex. He examined thousands of plant specimens and finally selected a variety of goldenrod. American tire manufacturer Harvey S. Firestone presented Edison with four automobile tires made of the new rubber. However, Edison's rubber proved to be less profitable than desired, and the project was abandoned.

Edison continued to work and experiment while suffering from several illnesses that struck him in his later years. He died in bed, at his home in Llewellyn Park, on Oct. 18, 1931.

Edison the man

Family and friends. On Dec. 25, 1871, Edison married Mary Stilwell, who had worked in one of his companies. The couple had three children—Marion Estelle; Thomas Alva, Jr.; and William Leslie. Edison nicknamed Marion and Tom "Dot" and "Dash" after the telegraph code. Mary died in 1884.

In 1885, Edison met Mina Miller, the daughter of a wealthy Ohio industrialist. Although she was only a few years older than Edison's daughter, Edison married her in early 1886. While her husband worked many hours, Mina developed an independent life of charitable and social activities. Edison and his second wife had three children—Madeleine, Charles, and Theodore. Of Edison's six children, Charles became the most famous. He served as secretary of the U.S. Navy in 1940 and as governor of New Jersey from 1941 to 1944.

Edison attracted friends through his storytelling, sense of humor, and fame. But the inventor-industrialist developed his strongest relationships among business associates. One of Edison's closest and most famous friends was Henry Ford. The industrial leaders became friends after Edison encouraged Ford to apply the gasoline engine to the automobile. The two friends later took automobile camping trips with Harvey Firestone and naturalist John Burroughs.

Philosophy. Always a man of ideas, Edison was well informed about technical matters, business, and current affairs. Journalists liked to interview him because he had a down-to-earth manner and a frank opinion on most matters. Edison had great faith in progress and industry. He believed that mass production offered people better jobs and more and cheaper goods. In addition, he said that inventing for industry offered everyone a chance for fame and wealth while benefiting society.

Edison valued long, hard work. Throughout his career, he spent many hours on his projects. With his saying, "Genius is 1 percent inspiration and 99 percent perspiration," Edison encouraged all people to work hard.

Edison lived in an era when business people aggressively marketed their goods. He was surrounded by a business philosophy that encouraged self-promotion. As a result, he often made claims and promises, then

Douglas C. Jones, Edison National Historic Site

The West Orange laboratory in New Jersey was Edison's workplace and true home for the last 44 years of his life. The laboratory's many rooms and buildings are now a national historic site. They feature exhibits of original inventions and working models developed by Edison.

found himself under great pressure to fulfill them. Yet he repeatedly met many of his promises and gained a reputation for innovation and quality.

Honors. From the time he invented the phonograph, Edison was honored throughout the world. France appointed him to the Legion of Honor in 1878, and the United States Congress gave him the Medal of Honor in 1928. Henry Ford brought Edison the biggest public attention with an international event called "Light's Golden Jubilee" in 1929. The celebration honored Edison and the 50th anniversary of his invention of the incandescent lamp. At the banquet that followed, U.S. President Herbert Hoover gave the principal address, and praises flowed in from prominent people from many nations.

Another tribute to Edison took place on the evening of his funeral, Oct. 21, 1931. At President Hoover's request, the lights were dimmed for a short time at the White House and in businesses and homes throughout the nation. Thus, momentary darkness was created to honor one who had brought light to many.

Four major historical sites and museums honor Edison. They include his birthplace in Milan, Ohio, and his winter home in Fort Myers, Florida. There is also the restored Menlo Park laboratory, which Ford moved from New Jersey to Greenfield Village in Dearborn, Michigan. The National Park Service manages the Edison National Historic Site at West Orange, which includes Edison's West Orange laboratory and the inventor's home in Llewellyn Park. Reese V. Jenkins

Related articles in *World Book* include:

Electric light (History)
Invention (The late 1800's)
Motion picture (The invention of motion pictures)
Phonograph (History)
Telephone (History)
Vacuum tube (Development of the vacuum tube)

Outline

I. **Early life**
   A. Boyhood
   B. The young telegrapher

II. **Inventor and businessman**
   A. Telegraph innovator
   B. The Wizard of Menlo Park
   C. Inventor-industrialist of West Orange

III. **Edison the man**
   A. Family and friends
   B. Philosophy
   C. Honors

Questions

How did Edison define genius?
What was Edison's first patented invention?
What are some important patents granted to Edison?
Why did people call Edison the Wizard of Menlo Park?
Why did Edison always work with assistants?
How was Edison venturesome in business as a youth?
What was one of Edison's projects that was not commercially successful?
What did Edison believe about mass production?
What was Edison's most significant achievement?
How did Edison make electric lighting practical?

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Edison Schools is a profit-seeking organization that manages public schools under contract with local school districts or charter school authorities. The organization's goal is to offer superior education for approximately the same amount per student that districts spend in their other schools. Edison's growing popularity has

stirred debate about what role—if any—nonpublic authorities should play in running schools funded with public tax dollars.

Edison hires its own administrators, teachers, and staff, and offers its own learning program. At Edison schools, both the school day and the school year are significantly longer than the United States average. Students in Edison schools generally have the same mix of abilities, ethnic backgrounds, and family income levels as do students in the rest of a district.

Edison Schools offers a comprehensive curriculum for kindergarten through grade 12. This curriculum stresses fundamentals of reading and mathematics in kindergarten through second grade. Emphasis on problem-solving, thinking, and writing increases as students mature. Edison also focuses on technology as a learning resource and a communication tool. The project uses narrative report cards, cumulative portfolios, and other nontraditional measures of student progress.

Media entrepreneur Chris Whittle founded the organization, originally called the Edison Project, in 1991. It was named for American inventor Thomas Edison to highlight the organization's commitment to inventiveness and technical creativity. Whittle assembled a team of experts in education, social science, and technology who spent three years developing the curriculum. The project opened its first schools in 1995. It changed its name to Edison Schools in 1999. Priscilla Wohlstetter

See also **Charter school; Edison, Thomas Alva.**

Editor. See **Journalism; Magazine; Motion picture** (Post-production); **Newspaper; Publishing.**

Editorial is usually a brief newspaper or magazine article that gives the publication's position on current events. It may also be a radio or television broadcast. It may criticize, praise, or merely discuss the actions of some public official or group. Newspaper editorials often encourage actions that the editor of the paper thinks will benefit the community. For instance, an editorial may back a campaign for more police officers. Editorials are also used to express strong political views.

Editorials often begin by stating an issue. They may conclude with advice, a plea, or a command. In style, they resemble essays (see **Essay**). Editorials usually are clearly marked when they appear in print. They often appear on a special editorial page. Maurine H. Beasley

See also **Pulitzer Prizes** (Prizes in journalism; table: Editorial writing).

Edmonds, Sarah Emma Evelyn (1841-1898), became the most famous woman soldier of the American Civil War (1861-1865). Edmonds, a Canadian, served in the Union Army disguised as a man. She used the name Frank Thompson.

Edmonds was born in December 1841 in New Brunswick, probably in Magaguadavic. She came to the United States in the 1850's. In 1861, she enlisted in a unit organized by a friend. She served mainly as a nurse and messenger. She also went on several spying missions to learn the size and location of Confederate troops. At times while spying, she pretended to be a black male laborer, a white female peddler, and a black female cook.

Edmonds gained fame when she wrote about her disguise and spying missions. In 1897, the Grand Army of the Republic, a group of Union Army veterans, made Edmonds its only woman member. Gabor S. Boritt

Edmonds, Walter Dumaux (1903-1998), an American author, became known for his novel *Drums Along the Mohawk* (1936), and other books on the history of upstate New York. He won the Newbery Medal in 1942 for his story for young people, *The Matchlock Gun* (1941). His *Bert Breen's Barn* (1975) won the 1976 National Book Award for children's literature.

Edmonds was born on a farm near Boonville, New York, on July 15, 1903. His first novel was *Rome Haul* (1929). Marc Connelly and Frank Elser adapted it into a play, *The Farmer Takes a Wife* (1934). Nancy Lyman Huse

Edmonton is the capital of Alberta and one of Canada's largest metropolitan areas in population. It is Alberta's second largest city. Only Calgary has more people. Edmonton lies in central Alberta, about 300 miles (480 kilometers) north of the Canada-United States border.

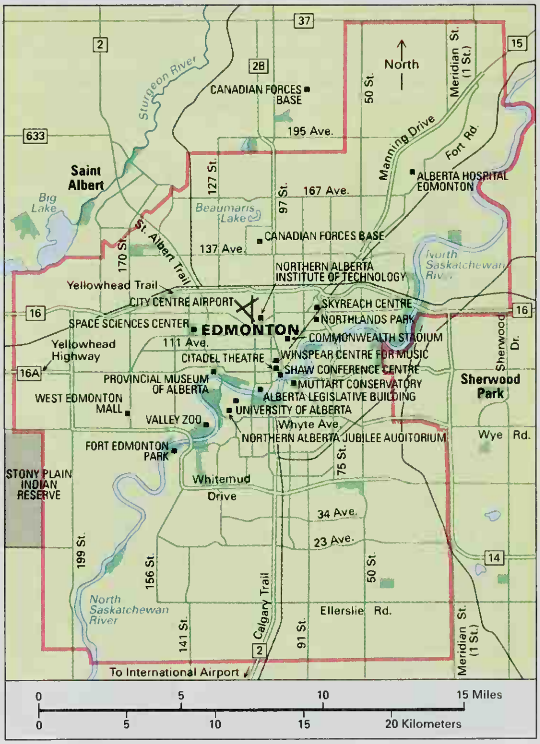
Edmonton stands at the crossroads of one of Canada's richest farm regions and the abundant natural resources of the country's northern area. Edmonton is the northernmost major city in North America and is called the *Gateway to the North.* Its location makes it a major dis-

City of Edmonton

Edmonton is the capital of Alberta. The map shows important points of interest in the city.

City boundary
Expressway
Other road
Railroad
Point of interest
Park

WORLD BOOK maps



Symbols of Edmonton. The flag's blue bars represent the North Saskatchewan River and strength. The white background of the crest signifies peace. The winged wheel stands for industry and aviation, the wavy ribbon for the river, and the sheaf for farming.

Facts in brief

Population: 666,104. *Metropolitan area population*—937,845.
Area: 264 mi^2 (684 km^2). *Area of metropolitan area*—3,637 mi^2 (9,419 km^2).
Altitude: 2,200 ft (671 m) above sea level.
Climate: Average temperature—January, 8 °F (−13 °C); July, 63 °F (17 °C). Average annual precipitation (rainfall, melted snow, and other forms of moisture)—18 in (46 cm). For the monthly weather in Edmonton, see Alberta (Climate).
Government: Mayor-council. Terms—3 years for the mayor and the 12 councilors.
Founded: 1795. Incorporated as a town in 1892. Incorporated as a city in 1904.

tributing point for goods traveling to and from Alaska and northwestern Canada. The city is a major refining, manufacturing, and distribution center for Alberta's petroleum and petrochemical industry.

The city covers 264 square miles (684 square kilometers). The North Saskatchewan River winds through Edmonton for 38 miles (61 kilometers). Parks and high-rise office and apartment buildings border the river on both banks much of the way.

In Edmonton, streets run north and south, and avenues run east and west. Most streets and avenues have numbers instead of names. The downtown area is bordered by 104 Avenue on the north, 97 Avenue on the south, 95 Street on the east, and 109 Street on the west.

The city's administrative offices, along with many commercial office buildings, are in the downtown area. The Alberta Legislative Building and other provincial government buildings stand on the north bank of the North Saskatchewan River at 109 Street.

West Edmonton Mall, in the city's west end, is a major retail and recreation center. Its features include hundreds of shops, a large indoor water park, an amusement park, movie theaters, and an ice rink.

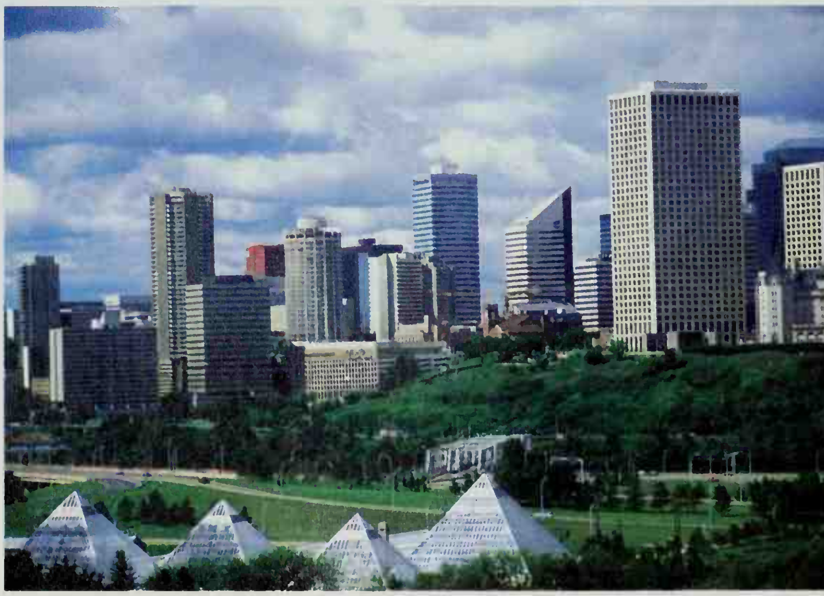
People. About 40 percent of the people in the Edmonton area have some British or Irish ancestry. Other large ethnic groups include people of German, Ukrainian, and Chinese descent. Many of Edmonton's people have a combination of ancestries.

Education. Edmonton has about 200 public schools, with a total enrollment of about 82,000. About 80 Roman Catholic schools serve approximately 32,000 children. Public funds support both school systems.

The province's first university, the University of Alberta, opened in 1908 in Strathcona, which later became part of Edmonton. Grant MacEwan College, Concordia University College of Alberta, King's University College, and the Northern Alberta Institute of Technology are also in Edmonton. Athabasca University is in nearby Athabasca. The Edmonton Public Library has a main library in downtown Edmonton and several branches.

Culture and recreation. The Provincial Museum of Alberta in Edmonton has exhibits on the history of Alberta. The City of Edmonton Archives specializes in the history of the city. The Alberta Aviation Museum and a space sciences center called the Odyssium are also in the city. The Edmonton Symphony Orchestra performs in the Francis Winspear Centre for Music. The Edmonton Opera Association and the Alberta Ballet Company also perform in the city. Many theatrical productions take place at Citadel Theatre. The city plays host to nu-

© Ron Watt, First Light



Edmonton is the capital of Alberta and the northernmost major city in North America. The Muttart Conservatory, *foreground,* is one of the city's most striking features. The conservatory's four glass pyramids house a variety of flowers and other plants.

merous arts fairs, including the Fringe Theatre Festival, the largest festival of its kind in North America.

Northlands Park, a large exhibition area, hosts livestock exhibits, rodeos, sports events, and trade shows. It is also the site of some of the activities that take place during Klondike Days, a fair held each July to celebrate the gold rush days of the 1890's.

Edmonton's Valley Zoo features many species of animals. Elk Island National Park, near the city, has a collection of North American animals, including bison.

Edmonton has about 9,400 acres (3,800 hectares) of parkland. The North Saskatchewan River valley contains North America's largest expanse of urban parkland. It covers 18,400 acres (7,450 hectares) in 22 parks. Fort Edmonton Park features a reconstruction of the fur trade fort from which the city developed. The park also highlights historic buildings from the city's past.

The Edmonton Eskimos of the Canadian Football League play their home games in Commonwealth Stadium. The Edmonton Oilers of the National Hockey League compete in the Skyreach Centre.

Economy. Petroleum distributing and processing and the production of petroleum products are Edmonton's leading industries. Many of Alberta's principal oil wells are within 100 miles (160 kilometers) of the city. Crude oil and natural gas are transported through western Canada's pipeline network to the city's numerous refineries and petrochemical producers. Some of the oil is carried from Edmonton to eastern Canada and the United States via pipelines. Products made from petroleum in Edmonton include chemicals and gasoline. Other goods produced in the city include fabricated metal products, foods and beverages, lumber and wood products, oilfield supplies, and plastics.

The Edmonton City Centre Airport, near downtown, was licensed in 1926 and is owned and operated by the city. The airport provides commuter service to locations in western Canada. Edmonton International Airport, which lies outside the city, provides national and international freight and passenger service. The Trans-Canada Yellowhead Highway runs through Edmonton. Two railroads serve the city.

Edmonton has two daily newspapers. They are *The Edmonton Journal* and *The Edmonton Sun.*

Government. The people of Edmonton elect a mayor to a three-year term. The city is divided into six *wards* (voting areas), and the voters of each ward elect two councilors to three-year terms on the city council. The city council sets policies for Edmonton and also appoints a city manager. The city manager is responsible for the daily operation of the city government. Edmonton receives revenue from property and business taxes and from provincial grants.

History. The Cree and Blackfoot Indians lived in the Edmonton area long before Europeans arrived. In 1795, the Hudson's Bay and North West companies built fur-trading posts on the North Saskatchewan River. The Hudson's Bay post was called Edmonton House. It later became known as Fort Edmonton. The name Edmonton comes from the English city of Edmonton. The trading posts moved several times before the two companies merged in 1821. Fort Edmonton became a regional fur-trading center. In 1830, Fort Edmonton was rebuilt near the present site of the Alberta Legislative Building. Edmonton grew into a town that was incorporated in 1892.

Edmonton received its city charter in 1904. When the province of Alberta was established the next year, Edmonton became the capital. In 1905, the Canadian Northern Railway (now part of the Canadian National Railway) linked Edmonton with Canadian cities to the east. The railroad brought many more settlers to Edmonton. Strathcona, a city on the south bank of the North Saskatchewan River, merged with Edmonton in 1912.

Bush pilots flying small planes into northern Canada used Edmonton as a base. An airport was licensed in Edmonton in 1926, and the city soon became a hub of aviation. During World War II (1939-1945), the U.S. Army constructed the Alaska Highway. The highway helped establish Edmonton as a distribution and transportation center for the northwestern part of North America.

The discovery of oil at nearby Leduc in 1947 brought petroleum companies to Edmonton. These companies built refineries and laid pipeline to carry oil and natural gas to other parts of Canada. Thousands of people came to Edmonton to work in the petroleum industry.

Much urban renewal occurred in Edmonton during the 1960's, and a building boom began in the 1970's. New office towers replaced old buildings in the downtown area. Modern shopping malls and industrial plants sprang up in various parts of the city and the metropolitan area. A light rail rapid-transit system for Edmonton opened in 1978 and has been expanded four times.

Edmonton has served as a site of international sports events. The Commonwealth Games, an athletic competition between nations of the British Commonwealth, were held in Edmonton in 1978. In 2001, Edmonton became the first North American city to host the International Amateur Athletic Federation (IAAF) World Championships in Athletics, a major track and field meet.

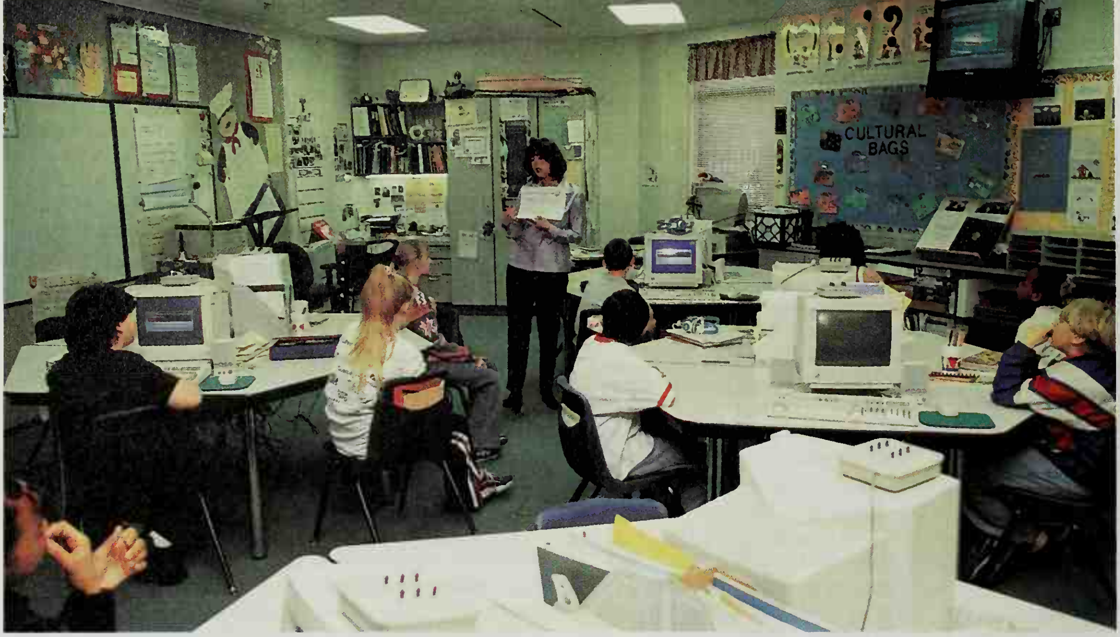
A tornado struck Edmonton on July 31, 1987. It killed 27 people and caused widespread property damage.

Today, Edmonton has one of Canada's most diversified economies. Technological advances of the 1990's have benefited the city's oil, gas, and chemical industries, as well as its transportation, tourism, and entertainment industries. Edmonton also has become a center for medical research and biotechnology. Patricia Beuerlein

See also Alberta (pictures).

Edom was an ancient kingdom that is mentioned often in the Old Testament. It stood southeast of the Dead Sea in what is now southern Jordan. Edom enjoyed its greatest prosperity between 1200 and the 700's B.C. The Old Testament describes the Edomites as descendants of Esau, the brother of Jacob (Genesis 36:1). Moses was not allowed to enter Edom on his journey to the promised land (Numbers 20:18-21). The Edomites spoke a language similar to Hebrew and probably worshiped many gods.

The country's rich copper and iron mines contributed to the splendor of the Kingdom of Israel, which had conquered Edom under David. Edom's prosperity began to decline in the 700's B.C. In the next 200 years, Judah, Assyria, and Babylonia ruled Edom. An Arab people called the Nabataeans invaded Edom during the Persian period of the 500's and 400's B.C. At the same time, many Edomites invaded southern Judah. They helped establish a territory there called Idumea. The Hasmonean dynasty conquered the Idumeans in the 100's B.C., and converted them to Judaism. H. Darrell Lance



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Education is the process of gaining knowledge and abilities. Although much learning occurs outside school, classrooms like this one are the main source of formal, organized education.

Education

Education is the process by which people acquire knowledge, skills, habits, values, or attitudes. The word *education* is also used to describe the results of the educational process. Ideally, education should help people develop an appreciation of their cultural heritage and live more satisfying lives. It should also enable people to become more productive members of society, both as citizens sharing in democratic processes and as workers in the economy. The most common way to get an education is to attend school. But much education takes place outside the classroom.

Education involves both learning and teaching. Sometimes, people learn by teaching themselves. But they also learn with the help of other people, such as parents or teachers. Parents are a child's first and perhaps most important teachers. They teach their children attitudes, habits, and values that help shape the children's character and remain with them throughout life. But few parents have either the time or the ability to teach their children everything the boys and girls need to know. Instead, parents turn over many educational responsibilities to professional educators.

Teachers and school district administrators have the chief responsibility for education. The organized instruction they provide is called *formal education*. Learning that results from less-organized instruction is called *informal education*.

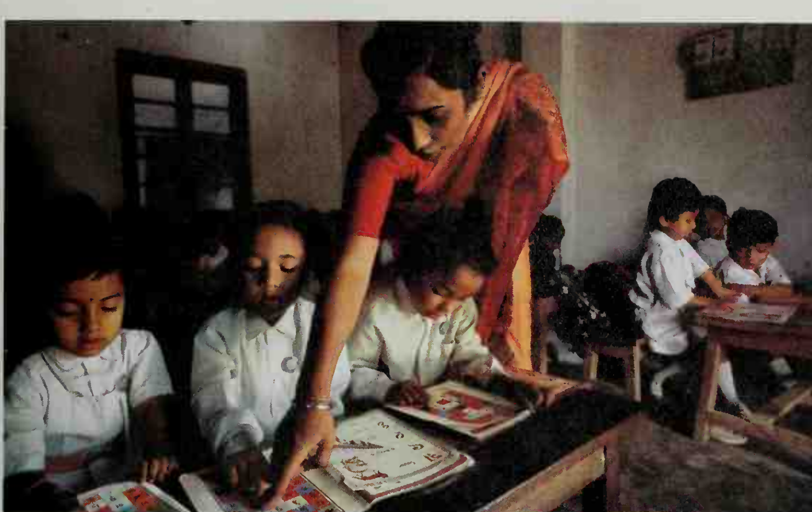
This article deals mainly with formal education, especially the kind given in schools. But many other institutions and agencies also provide education. Churches, which are established mainly for worship, educate their members through church teachings. Libraries, newspapers, and such organizations as the Boy Scouts, Girl Scouts, and 4-H also educate people. Radio and television are especially effective means of education. For example, various TV programs provided by public television stations give millions of children in the United States valuable learning experiences. Since the late 1970's, computers have become important in education. Widespread use of word processing and financial software has helped people to be more productive. Also, the ability to quickly search for information on the Internet, a worldwide network of connected computers, has begun to change the way formal education is provided.

Education is as old as humanity. To survive, prehistoric people had to educate their children to hunt animals or to plant and harvest grains, fruits, and vegetables for food. Prehistoric peoples also had to learn to cooperate and to live together peacefully. They found that they could not live together peacefully for long unless they learned to act in certain ways. Education taught them how to act and so helped make society possible.

A society that reaches a relatively complex level of development is called a *civilization*. For a society to achieve this level, its members must learn a great deal. They must become skilled in agriculture, commerce, government, industry, and the arts. Education is the chief means of acquiring and teaching the essential knowledge and skills. A modern society would not survive without education. See **Civilization**.

Education is more important today than ever before. It helps people acquire the skills they need for such everyday activities as reading a newspaper or managing their money. It also gives them the specialized training they may need to prepare for a job or career. For example, people must meet certain educational requirements and obtain a license or certificate before they may practice accounting, law, or medicine. Many fields, such as computer or police work, require special training. Also, there is considerable evidence that people who achieve higher levels of education earn higher wages.

The contributor of this article is Lawrence O. Picus, Director of the Center for Research in Education, University of Southern California.



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Elementary education provides students with basic skills, such as reading and writing, that they will use throughout life. This teacher in India is helping her students learn the alphabet used to write the Hindi language.

© Barbara Filet, Stone

Informal education takes place in a variety of settings outside school, including libraries and museums. This family is learning about racing cars from an interactive display at an automotive museum in Los Angeles.

Education is important because it helps people increase their knowledge and understanding of the world. Education helps people acquire skills that make their lives more interesting and enjoyable. Such skills include those needed to participate in a sport, paint a picture, or play a musical instrument.

Education also helps people adjust to change. This benefit has become increasingly important because social changes today take place with increasing speed and affect the lives of more and more people. Education can help a person understand these changes and provide the skills for adjusting to them.

Some educators study the *objectives* (goals) of education. This has led to the classification of educational objectives into three areas: (1) the *cognitive area,* (2) the *affective area,* and (3) the *psychomotor,* or *locomotor, area.*

The cognitive area aims at increasing a person's knowledge and intellectual skills. It deals with the ability to think and reason effectively. The largest proportion of educational objectives involves the development of abilities in this area.

The affective area deals with feelings, values, and appreciations. It aims at helping an individual develop moral and spiritual values and healthy attitudes and emotions. Such education is often called *character education* or *citizenship training.*

The psychomotor area includes the development of a person's muscular or mechanical skills. These abilities are often related to courses in handwriting, speech, and physical education, and to vocational and technical courses. The skills range from learning to use crayons to learning an intricate ballet movement.

Most countries consider education one of the most important areas of public life. Countries throughout the world invest large amounts of time, money, and other resources to provide education for their citizens. Almost 20 percent of all the people in the world are directly involved in education as students or teachers in elementary schools, middle or junior high schools, high schools, colleges, or universities. In industrialized countries, such as Canada, Japan, the United Kingdom, and the United States, about 25 percent of the people are di-

rectly involved in education. Millions more people hold nonteaching jobs related to education. These jobs include school cafeteria workers, nurses, and secretaries; school bus drivers; textbook publishers; and producers of educational materials and equipment.

Kinds of education

The school systems of all modern nations provide both *general education* and *vocational education.* Most countries also provide *special education* programs for children with disabilities or other special needs. *Adult education* programs are provided for people who wish to complete or improve their education after they no longer participate in regular elementary and *secondary schools* (high schools). Colleges and universities also provide a wide range of education programs for people who want to continue their education beyond high school.

General education aims at producing intelligent, responsible, well-informed citizens who take an active interest in the world around them. It is designed to transmit a common cultural heritage rather than to develop trained specialists.

Almost all elementary education is general education. In every country, elementary school pupils are taught skills they will use throughout life, such as reading, writing, and arithmetic. They learn moral values and the rights and duties of citizenship. They also receive instruction in a variety of subjects, including geography, history, and science. In industrialized countries, almost all young people continue their general education in secondary school. Most college students are also required to take some general education courses.

In most Western nations, advanced general education is frequently called *liberal education.* Liberal education aims at broad mental development. Students are taught to investigate all sides of a question and all possible solutions to a problem before reaching a conclusion or planning a course of action. The branches of learning that aid in this development are called the *liberal arts.* The liberal arts include the humanities, mathematics, and the biological, physical, and social sciences. Liberal education is important to democracies because the quality of government in such a society depends on the ability of its citizens to judge ideas and events intelligently. As a result, most school systems require students following a vocational program to also take some liberal arts courses.

Vocational education aims primarily at preparing individuals for a job. Some high schools, called *vocational high schools,* specialize in vocational programs. Vocational high school students are also required to take some general education courses. Community colleges and specialized schools offer advanced vocational and technical training. Universities and separate professional schools prepare students for careers in such fields as architecture, business, engineering, law, medicine, nursing, teaching, and theology.

Many businesses and industries conduct vocational programs to help their employees develop new skills and improve the quality of products and services. One type of education, known as *human resource development* (HRD), helps employees learn precisely what to do in their jobs and how to work as part of a team. HRD is usually referred to as *training.* Instructors in HRD are generally called trainers rather than teachers.

Jeffrey Silvester, FPG

Special education programs provide instruction for disabled or gifted students. This teacher is helping a hearing-impaired child learn how to recognize and pronounce words.

Vocational education is important in countries striving to develop an economy based on modern technology. It is especially important in developing countries in Africa, Asia, and Latin America. To help build their country's economy, governments encourage students to take courses in such fields as agriculture and industry. See **Vocational education.**

Special education provides educational opportunities for people with disabilities or special talents. Most countries support special education programs for people who have difficulty hearing, seeing, or speaking; are emotionally disturbed; or are physically or mentally disabled. Some programs also serve people with autism, orthopedic impairments, severe brain injuries, certain health impairments, or specific learning disabilities. In the United States, most programs for people with disabilities are conducted by local public schools aided by state and federal funds. Some local school systems also provide special education programs for gifted students. Such programs offer the students the special facilities and guidance they need to develop their talents. In the United States, 10 to 12 percent of schoolchildren are identified as having disabilities that require some form of special education. The number of students identified as gifted and receiving special services varies among school districts, but generally averages about 5 percent of total enrollments.

Adult education. Most countries support general and vocational education programs for adults. Such *continuing education* programs enable adults to continue their formal education or develop a particular skill or hobby. Courses range from elementary reading, arithmetic, and foreign languages to advanced commercial, technical, and professional training. In the United States, many adults take advantage of a series of tests called the General Educational Development Tests (GED) to earn a certificate equal to a high school diploma.

Millions of adults participate in some kind of adult education. Many colleges and universities provide *extension courses,* which give adults an opportunity to take college-level courses. Many extension courses are scheduled for evening hours so that they can be attended by people who work during the day. Governments sponsor many adult education programs, including programs for people in the armed forces. Businesses, community agencies, correspondence schools, hospitals, industries, labor unions, libraries, museums, prisons, and television stations provide various organized educational opportunities for adults. For further information, see **Adult education.**

Education in the United States

Unlike most other countries, the United States does not have a national educational system. Instead, each state is responsible for organizing and regulating its own system of education. The systems organized by the various states have much in common. This section discusses how the state systems are organized, controlled, and supported. It also discusses the role of the federal government in education.

The organization of U.S. education. Formal education in the United States is divided into various stages or levels that are arranged somewhat like the rungs of a ladder. *Early childhood education* is the first rung of the educational ladder. It is followed by *elementary education, intermediate education, secondary education,* and *higher education.* Ordinarily, students complete one stage before they continue to the next.

School attendance is *compulsory* (required) in every state. The age through which attendance is required varies among the 50 states, ranging from 15 to 18 years of age. Many states make exceptions to the age requirements. In most states, for example, students fulfill the attendance requirements when they graduate from high school, even if they have not reached the required age.

Early childhood education is generally designed for children 5 years of age and younger. Its chief aim is to develop the habits, attitudes, and skills that provide readiness for school. Children who develop an interest in learning before they enter elementary school are more likely to do well in school than children who have not developed such an interest. In the United States, about two-thirds of all children from age 3 through age 5 attend some kind of early childhood education program. Early childhood programs are of two main types: (1) nursery schools, also called preschools, and (2) kindergartens.

Individuals, private organizations, and some school systems operate nursery schools. Most nursery schools are designed for children 3 or 4 years old. The children learn to get along in a group supervised by a teacher. They are encouraged to express feelings and ideas through building, dancing, drawing, playing, singing, and speaking. Some nursery schools use a teaching method developed by the Italian educator Maria Montessori. The Montessori method recommends the use of special teaching materials and learning tasks to help children develop awareness, confidence, and independence (see **Montessori method**).

The federal government sponsors a special type of nursery school program called Head Start. The program has helped set up thousands of nursery schools called Head Start centers for young children from low-income families. The centers provide the children with learning experiences they may not receive at home. Research has shown that this program has succeeded in preparing disadvantaged students for school. See **Head Start.**

Various public and private organizations sponsor *daycare,* or *child-care, centers* for children. Some of these centers resemble nursery schools, but others simply provide care for young children and do not offer planned education. See **Day care.**

Most school systems and many private organizations operate kindergartens, intended mainly for 5- and 6-year-olds. Kindergartens offer more advanced activities than do most nursery schools. They help prepare children for the learning experiences that follow in elementary school. See **Kindergarten; Nursery school.**

Elementary education. Children attend elementary school from about age 6 or 7 to about 11 or 12 (or older if the school goes through the eighth grade). Most ele-

© Lawrence Migdale

Continuing education programs enable adults to continue to learn. Some adults, such as these senior citizens who are studying painting, want to learn new skills to use in their leisure time.

mentary schools provide kindergartens for children who are 5 or 6 years old, though elementary education itself usually begins in first grade. Most U.S. communities have at least one elementary school. Elementary schools are also called *grade schools* or *grammar schools*.

A traditional elementary school offers educational programs for children in kindergarten through fifth grade, called K-5, or kindergarten through sixth grade (K-6). Some schools provide programs for grades K-8. Children of similar age are usually in the same grade. They meet in the same classroom with the same teacher for most or all of the day. This traditional arrangement is sometimes called a *self-contained classroom*. Some self-contained classrooms may include students from more than one grade level. The pupils are supposed to meet the standards for their age group before being promoted to the next grade. But promotion practices differ from school to school.

Some communities have *nongraded,* or *ungraded,* schools. Nongraded schools do not group the pupils according to age. Instead, pupils of different ages meet together for certain subjects or activities. The teachers encourage each student to advance at his or her own rate. Frequently, the groups are composed of children with similar abilities or interests. In most nongraded schools, pupils receive general evaluations rather than specific grades. Achievement tests indicate a pupil's progress. Pupils transfer to a secondary school when they reach the required age, provided that their progress is satisfactory. Nongraded plans of organization are also called *continuous progress plans*.

Some elementary schools use a teaching method called *team teaching*. In these schools, teachers are organized into groups called *teams*. Each team is responsible for a large group of students. Each teacher on a team may teach a certain subject or a certain part of a unit of study to the entire group. Or the pupils may be divided into smaller groups to allow more time for individual instruction and group discussion. See **Elementary school.**

Intermediate education. Since the 1960's, there has been an increased emphasis on the intermediate or middle grades. As a result, most school districts today offer special programs for the middle grades. These middle school or junior high school programs are designed to help students make the transition from elementary schools to the more demanding structures of secondary schools. The grade structures of these schools vary widely. Most offer grades 6-8, but such combinations as grades 6-7, 7-8, and 7-9 are also common. Some intermediate schools include grade 5 as well.

In some schools, children in the middle grades receive instruction in self-contained classrooms, while in others students attend different classes with different teachers for each subject. This arrangement is known as *departmentalized instruction*. Many intermediate schools today offer a combination of the two, with students spending part of their day in a self-contained classroom and the rest of the day moving among departmentalized classes. See **Junior high school; Middle school.**

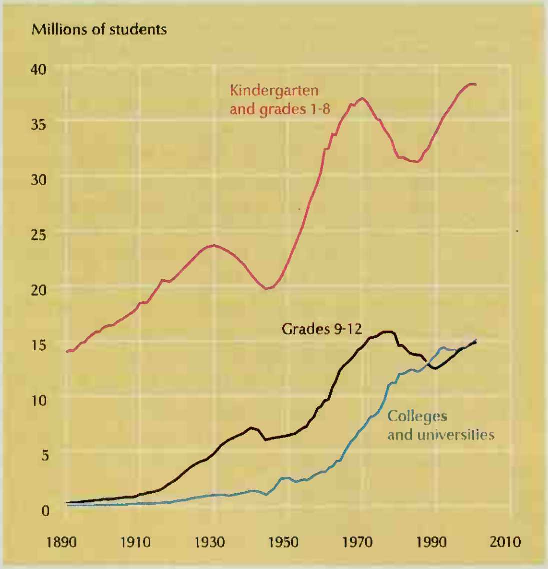
Secondary education. Secondary education in the United States is the responsibility of senior high schools. It is designed to help students become responsible members of the community and to prepare them for a job or for advanced studies after graduation. High school graduates receive a diploma to show that they have completed their secondary education. Almost all the young people in the United States enroll in high school, and most remain through graduation.

Many communities have four-year high schools with grades 9 through 12. Others offer high school programs for students in grades 10-12. These schools enroll students who have completed middle or junior high school, or an eight-year elementary school program. Some high schools are nongraded and operate much as nongraded elementary schools do.

Most high schools offer both general and vocational courses of study. These schools are called *comprehensive high schools*. Students who plan to continue their education after high school usually take a general, or *college preparatory,* course of study. Many high schools make *advanced placement* classes available to college-bound students. Students who pass these courses, and meet a certain minimum score on a nationally adminis-

School enrollment in the United States

The graph below shows the changes in U.S. public and private school enrollment since 1890. The table gives the number of students enrolled during selected years.

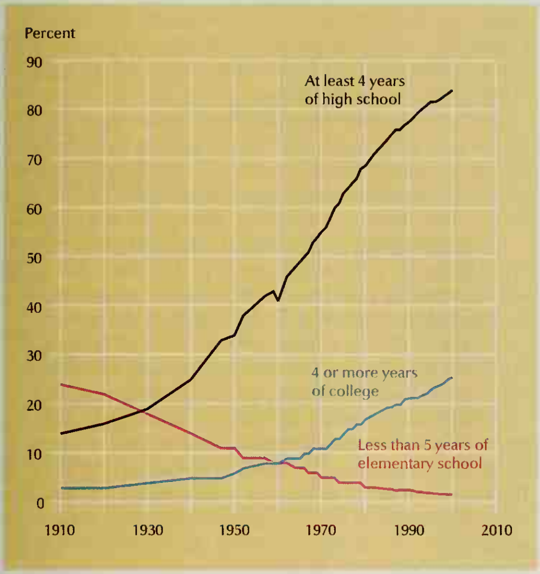


Year	Kindergarten and grades 1-8	Grades 9-12	Colleges and universities
1890	14,036,000	298,000	157,000
1900	16,262,000	669,000	238,000
1910	18,529,000	1,115,000	355,000
1920	20,964,000	2,500,000	598,000
1930	23,740,000	4,812,000	1,101,000
1940	21,127,000	7,130,000	1,494,000
1950	22,207,000	6,453,000	2,659,000
1960	32,412,000	9,600,000	3,216,000
1970	37,011,000	14,418,000	7,136,000
1980	31,639,000	14,570,000	12,097,000
1990	33,973,000	12,475,000	13,819,000
1995	36,806,000	13,697,000	14,262,000
2001	38,255,000	14,902,000	15,300,000

Source: U.S. Department of Education.

Years of schooling completed

Since 1910, the percentage of Americans age 25 and over with four years of high school or college has risen sharply. The percentage with under five years of grade school has fallen.



Sources: U.S. Bureau of the Census; U.S. Department of Education.

tered advanced placement examination, can earn college credit.

Students who intend to get a job immediately after graduation may choose a vocational course of study. Some large school systems operate separate vocational high schools. Many states, however, have recently changed high school graduation requirements to include more college preparatory coursework. As a result, many vocational programs have experienced drops in enrollment. See **High school.**

Higher education is education beyond high school. More than half of all high school graduates in the United States get some advanced schooling. The United States has several thousand institutions of higher learning. Over half are privately owned and operated, and most of these are small liberal arts colleges. Many of the publicly owned institutions of higher learning are large state universities. About four-fifths of all the college and university students in the United States attend public institutions.

Institutions of higher learning include a wide variety of community colleges, technical institutes, colleges, universities, and separate professional schools. Community colleges offer two-year programs in both general and career education. Most technical institutes offer two-year programs in such fields as automotive engineering, business, and electronics. After completing a two-year course at a community college or technical institute, a student receives an associate's degree—or a certificate in the case of certain types of specialized training. Colleges and universities provide a wide selection of liberal arts and career programs. Most offer a four- or five-year liberal arts program that leads to a bachelor's degree.

Many colleges and most universities offer advanced courses leading to a master's or doctor's degree. Most universities also have professional schools, which provide training and award degrees in such fields as business, dentistry, education, engineering, law, and medicine. Students ordinarily must complete a certain amount of college work before gaining admission. Some professional schools are not connected with a university but award the same kinds of degrees as do professional schools of universities. See **Community college; Universities and colleges.**

Control and support of U.S. education. The Constitution of the United States makes no mention of education. The 10th Amendment, however, gives the states any powers the Constitution does not prohibit or specifically grant to the federal government. Because the Constitution does not give the federal government control over education, the states automatically have this power. But the Constitution gives Congress the power to provide for the "general welfare of the United States." Congress has used this power to deal with educational matters that affect many Americans.

Control. Every state has passed laws governing education and has set up a system of public schools. A state school system provides facilities for every level of education, from early childhood education through higher education. Parents may send their children to public schools, or they may enroll them in private schools that are independent of state control. Private schools controlled by religious groups are generally called *parochial schools.* The Roman Catholic Church maintains most of the parochial schools in the United States.

Various court decisions have held that parents may even educate their children at home. But the children must receive an education equal to that of public school pupils. A state may test children educated outside the public school system to ensure that they meet standards set for students who attend public schools.

Every state except Hawaii has transferred some of its control over public education to local school districts. Under rules set by the state, a school district is responsible for running the local public schools, including such tasks as hiring teachers, constructing buildings, and planning courses of study. Each state government determines the number and composition of school districts in the state. Some large districts include all or part of a city or county. Other school districts are much smaller and may consist only of a rural township or community. In some states, all school districts include grades K-12, while in other states there are elementary (K-6 or K-8) districts and high school (7-12 or 9-12) districts instead of, or in addition to, K-12 districts.

Since the early 1990's, many states have allowed the establishment of *charter schools.* Charter schools typically are independent of government. They receive a charter for their operation either from the local school district, from another public institution such as a state university, or from the state board of education. The organization of charter schools varies because of differences in charter school legislation from state to state, and the preferences of those who establish the school. See **Charter school.**

Financial support for U.S. public education comes almost entirely from local, state, and federal tax money.

Private schools are supported mainly by tuition fees and by contributions from churches, private organizations, wealthy donors, and former students.

In the past, almost all the money needed to support the public schools came from local *property taxes.* Citizens pay property taxes based on the value of buildings, land, and certain other items that they own. Over time, as the cost of education increased, and as taxpayers began to resist increases in property taxes, states began to provide more support for the cost of education.

State funds are used both to increase available resources for schools, and to help equalize differences in the ability of local school districts to raise property taxes. Many legal experts and educators consider property taxes an unfair method of supporting public schools. For more information about property taxes and school financing, see the section *How should education be financed?* later in this article.

Local school districts raise almost half of the total cost of U.S. public elementary and secondary education. The states provide most of the remaining half of the necessary funds. In most districts, federal tax dollars pay only a small percentage of school funding costs.

The federal government and education. Various agencies and branches of the federal government deal with educational matters. Congress decides how much money the government will spend on education and what types of programs federal funds will support. Many federal departments and agencies are responsible for distributing the funds and managing the programs approved by Congress. The Supreme Court of the United States and other federal courts decide constitutional questions relating to education.

The chief educational agency of the federal government is the United States Department of Education. The department finances and administers programs to improve education. These programs include aid for elementary, secondary, and higher education, as well as for special education and vocational education. The department also conducts educational research. The National Center for Education Statistics, a division of the department, collects and publishes information on educational activities in the United States.

The federal government aids and encourages education in two main ways. (1) It tries to ensure that all children are granted equal educational opportunities. (2) It provides funds for certain types of education when such financial aid seems beneficial to the nation as a whole.

Ensuring equal opportunity. The federal government cannot directly control education in the states. But it can insist that every state provide equal educational opportunities for all its citizens. For example, in the historic 1954 case of *Brown v. Board of Education of Topeka,* the Supreme Court ruled that compulsory segregation of the races in public schools was unconstitutional. The court held that separate facilities for black and white students were "inherently unequal," and in 1955 ordered states with segregated schools to open them to all races. These rulings led to actions to assure equal opportunity for such groups as women, people with disabilities, and people who do not speak English. The section in this article titled *Education for whom?* gives further information about equal opportunity.

Providing financial aid. The federal government spends billions of dollars a year on education. Some of this money supports educational institutions owned and operated by the federal government. These schools include the air force, military, and naval academies;

Expenditures for education in the United States*

These graphs show the yearly expenditures for U.S. education since 1930 and these expenditures as a percentage of U.S. *gross domestic product* (GDP). GDP is the total value of goods and services produced within a country annually. Larger enrollments and rising prices have contributed to a rapid increase in school expenditures since 1950.

*Includes operating costs, capital outlays, and interest for all public and private schools from kindergarten through graduate school.
Sources: U.S. Department of Education; U.S. Department of Commerce.

Students, teachers, and school expenditures

United States	Number in private schools*		Number in public schools*		Public school expenditures†	
	Students	Teachers	Students	Teachers	Per student	Total
Alabama	73,400	5,900	740,700	48,600	$ 5,500	$ 3,880,000,000
Alaska	6,200	600	134,400	7,800	9,200	1,138,000,000
Arizona	44,100	3,300	852,600	43,900	5,200	3,963,000,000
Arkansas	26,400	2,100	451,000	31,400	5,200	2,241,000,000
California	619,100	43,200	6,038,600	287,300	6,000	34,380,000,000
Colorado	52,100	4,400	708,100	40,800	6,400	4,141,000,000
Connecticut	70,100	6,900	554,000	39,900	9,600	5,076,000,000
Delaware	22,800	1,800	112,800	7,300	8,300	873,000,000
District of Columbia	16,700	1,900	77,200	4,800	10,600	694,000,000
Florida	290,900	22,900	2,381,400	130,300	6,400	13,534,000,000
Georgia	116,400	10,700	1,422,800	90,600	6,500	8,537,000,000
Hawaii	33,200	2,500	185,900	10,900	6,600	1,144,000,000
Idaho	10,200	800	245,300	13,600	5,400	1,240,000,000
Illinois	299,900	19,600	2,027,600	124,800	7,700	13,603,000,000
Indiana	105,500	7,400	988,700	58,900	7,200	6,697,000,000
Iowa	49,600	3,500	497,300	33,500	6,500	3,111,000,000
Kansas	43,100	3,200	472,200	33,000	6,700	2,841,000,000
Kentucky	75,100	5,500	648,200	42,000	6,400	3,646,000,000
Louisiana	138,100	9,200	756,600	50,000	6,000	4,265,000,000
Maine	18,300	1,800	209,300	16,300	7,700	1,510,000,000
Maryland	144,100	12,200	846,600	51,000	7,900	6,166,000,000
Massachusetts	132,200	12,500	971,400	77,600	8,800	7,949,000,000
Michigan	179,600	11,800	1,725,600	96,100	8,100	12,785,000,000
Minnesota	92,800	6,500	854,000	56,000	7,200	5,816,000,000
Mississippi	51,400	3,900	500,700	30,700	4,900	2,293,000,000
Missouri	122,400	9,100	914,100	63,900	6,400	5,348,000,000
Montana	8,700	700	157,600	10,400	6,800	956,000,000
Nebraska	42,100	3,000	288,300	20,800	6,900	1,821,000,000
Nevada	13,900	1,000	325,600	17,400	5,900	1,738,000,000
New Hampshire	23,400	2,200	206,800	14,000	6,800	1,317,000,000
New Jersey	198,600	15,500	1,289,300	95,900	10,700	12,875,000,000
New Mexico	23,100	2,000	324,500	19,800	5,400	1,788,000,000
New York	475,900	37,200	2,887,800	202,100	10,500	26,885,000,000
North Carolina	96,300	9,000	1,275,900	81,900	6,100	7,098,000,000
North Dakota	7,100	500	112,800	8,200	5,800	625,000,000
Ohio	254,500	16,200	1,836,600	116,200	7,300	12,207,000,000
Oklahoma	31,300	2,700	627,000	41,500	5,700	3,333,000,000
Oregon	45,400	3,500	545,000	27,800	7,800	3,706,000,000
Pennsylvania	339,500	24,500	1,816,700	114,500	8,000	13,532,000,000
Rhode Island	24,700	2,000	156,500	11,000	9,000	1,284,000,000
South Carolina	55,600	4,900	666,800	45,500	6,000	3,759,000,000
South Dakota	9,400	700	131,000	9,400	5,600	697,000,000
Tennessee	93,700	7,900	916,200	60,700	5,500	4,639,000,000
Texas	227,600	19,800	3,991,800	267,900	6,200	22,430,000,000
Utah	12,600	1,100	480,300	21,800	4,500	2,026,000,000
Vermont	12,200	1,400	104,600	8,500	8,000	793,000,000
Virginia	100,200	9,400	1,134,000	81,100	6,100	7,137,000,000
Washington	76,900	5,700	1,003,700	50,400	6,600	6,098,000,000
West Virginia	15,900	1,500	291,800	21,100	7,200	1,987,000,000
Wisconsin	139,500	10,000	877,800	60,800	8,100	6,621,000,000
Wyoming	2,200	200	92,100	6,900	7,400	652,000,000
Total	5,163,000	395,800	46,857,600	2,906,600	7,000	302,875,000,000

*Figures are for fall 1999.
Source: U.S. Department of Education.

†Figures are for 1998-1999 school year and include construction and other capital outlays.

Canada	Number in private schools		Number in public schools‡		Expenditures§	
	Students	Teachers	Students	Teachers	Per student	Total
Alberta	24,720	1,960	541,600	28,000	$ 6,800	$ 3,872,000,000
British Columbia	59,290	3,560	616,600	30,300	7,200	4,899,000,000
Manitoba	14,100	840	208,900	11,700	7,600	1,691,000,000
New Brunswick	770	70	130,000	7,400	6,600	862,000,000
Newfoundland and Labrador	380	40	97,700	6,400	5,900	583,000,000
Northwest Territories#	0	0	18,000	1,300	11,500	207,000,000
Nova Scotia	2,520	230	160,600	9,300	6,300	1,027,000,000
Ontario	90,600	7,050	2,038,000	110,000	8,000	17,108,000,000
Prince Edward Island	250	10	24,200	1,400	5,800	143,000,000
Quebec	102,610	5,690	1,022,500	63,000	6,900	7,750,000,000
Saskatchewan	2,570	200	207,200	11,300	6,500	1,372,000,000
Yukon Territory	0	0	6,200	400	12,600	78,000,000
Total	297,800	19,650	5,071,500	280,500	7,400	39,592,000,000

‡Includes public and federal schools, and schools for the hearing and visually impaired.
#Includes figures for what is now Nunavut, which became a separate territory on April 1, 1999.

§Expenditures are in Canadian dollars and include both public and private schools.
All figures are for the 1998-1999 school year.
Source: Statistics Canada.

schools for American Indian children; and schools for the children of military personnel and government employees overseas. The largest federal educational expenditures are for higher education and for certain educational programs administered by the states.

The federal government grants large sums to state departments of education. Some of the money is used to support state educational programs. But most of the funds are distributed among local school districts, which may use them for purposes specified by Congress. Congress grants large sums to local districts to provide special services for children from low-income families. Local districts also receive federal funds to purchase textbooks, pay for school health services, and finance experimental education programs. A district must make these programs and services available to all children, including those who attend private schools.

The federal government pays about 13 percent of the total costs of higher education in the United States. The government grants loans and scholarships to college and university students to help pay their tuition and other school expenses. The government also grants funds to public and private institutions of higher learning. Without federal aid, many colleges and universities would be forced to close.

Education in Canada

Canada, like the United States, does not have a national educational system. Instead, each province and territory organizes and regulates its own system of education. The national government controls schools for Indians, Inuit (formerly called Eskimos) schools, and schools for children of Canadian military personnel overseas.

Public education is free throughout Canada. Most private schools charge tuition fees. Children are required to attend for 10 years in most provinces. Most communities offer education to students from kindergarten through 12th grade. Students who plan to seek employment after completing their required education can take a two-year vocational course in high school. Students who plan to continue their education take a four- or five-year general or vocational course.

Canada has dozens of degree-granting institutions that are members of the Association of Universities and Colleges of Canada. Other institutions of higher learning include technical institutes and community colleges. In Canada, a community college combines the last one or two years of high school and the first one or two years of college.

Each province has a department of education headed by a minister of education. The department sets educational policies and standards for the entire province. A province is divided into local school districts, each of which has a school board and a superintendent. Local districts have considerable control over their schools.

Provincial governments share the cost of education with local school districts. In six provinces—Alberta, British Columbia, Newfoundland and Labrador, Ontario, Quebec, and Saskatchewan—public funds are used to support religious schools. The other provinces give little or no aid for religious schools. Many Roman Catholic schools, especially in Quebec, teach in French. Most Protestant and nonreligious schools teach in English.

Education around the world

Most nations divide education into the same stages as does the United States. Thus, formal education in these nations begins with early childhood education and continues through elementary, secondary, and higher education. But unlike the United States, most other countries have an educational system that is completely or partly administered by the central government.

Nations vary greatly in the kind of education they provide and in the amount of schooling they require. They also vary in their ability to provide teachers and schools and in their manner of controlling and supporting education. Some nations, including most of those in Europe and North America, have well-developed economies and long-established educational systems. Almost all children in these developed countries receive at least an elementary education, and most also receive a secondary education. As a result, the developed nations have high *literacy rates* (percentages of citizens who can read and write). Most less developed countries, on the other hand, have low literacy rates. Many of these countries have a serious shortage of teachers and classrooms. Many children do not receive even an elementary education. A number of developing countries, such as Cape Verde and the Dominican Republic, use radio to broadcast educational programs to people in remote areas.

This section discusses education around the world. See the individual country articles for a detailed discussion of education in each country.

Organization. Many nations provide early childhood education in schools similar to American nursery schools and kindergartens. In almost every nation, elementary education is compulsory and free. In every country, the elementary schools teach children to read and write and to work with numbers. The pupils also learn their country's customs and their duties as citizens. In most countries, the pupils also study such subjects as geography, history, and science.

In many countries, the majority of children receive only an elementary education. Secondary and higher education are available only to outstanding students or to those who can afford private schools. These nations include most less developed countries, some East European countries, and such West European nations as Portugal and Spain. France, Japan, the United Kingdom, and other highly developed countries require all young people to complete from 9 to 11 years of school, including 3 or 4 years of secondary school. Most countries have junior secondary schools. Their purposes are about the same as those of junior high schools and middle schools in the United States.

Unlike most school districts in the United States, the school systems of most other countries provide more than one kind of secondary school. For example, students in most European countries may attend a general school, which specializes in academic subjects, or they may attend a vocational school. Some of the vocational schools prepare students for advanced vocational or technical training. Others train students to enter a business or a trade immediately after they graduate. In many European countries, secondary school students may hold jobs and complete their education by taking part-time courses.

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Education in Vietnam, *shown here,* and in some other countries is entirely controlled by the government. The majority of countries, however, have both public and private schools.

In many countries, students take an examination to determine what kind of secondary school they will attend. Some students are admitted to academic schools, which prepare them for advanced studies in a university. Other students go to vocational schools. Some countries with two or more systems of secondary schools are changing to the system used in the United States. The United Kingdom, for example, has replaced many of its specialized secondary schools with comprehensive high schools.

In most countries, the percentage of young people who receive a college education is much smaller than in the United States. A few extremely poor nations do not have a single college or university. But most countries have at least one institution of higher learning. The developed countries of Europe and Asia have many colleges and universities. Most of these countries also have advanced technical and professional schools.

In almost every country, students must complete their secondary education and pass an entrance examination before they may be admitted to an institution of higher learning. In many countries, the exam results determine what kind of higher education a student may get.

The educational system of almost every nation includes some type of school for students with disabilities.

School enrollment throughout the world

Enrollment ratios* by level of education

Major region	K-6	7-12	College and graduate
Africa	81	34	7
Asia	106	57	11
Europe	105	99	43
Latin America	114	62	19
North America	102	101	85
Oceania	100	111	58
World	102	60	17

*Enrollment ratios compare the number of students enrolled to the population which, by age, should be enrolled. A ratio higher than 100 indicates that students older or younger than the typical age range are also enrolled.
Figures are for 1997.
Source: United Nations Educational, Scientific and Cultural Organization.

Most countries also provide for adult education at all levels. Many developing countries support schools that teach adults to read and write.

Boarding schools are important in some countries. Boarding school students live at school rather than at home. Europe has many boarding schools for the children of wealthy families. Some educators believe that social values can be taught more effectively if students live at school. This also makes it easier for parents to work. Israel has collective communities called *kibbutzim,* in which children spend most of their time together.

Control. In some countries, including China, all education is publicly controlled. Private schools are prohibited. The majority of countries have both public and private schools. In most of these countries, the majority of elementary- and secondary-school children attend public schools. The Netherlands is one of the few nations in which more children are enrolled in private schools at all levels than in public schools.

In most nations, the central government has at least some control over the public school system. In France, the national government has complete control over the public schools. A national *ministry* (department) of education decides all questions of educational policy and manages the local public schools.

In many other countries, including most European nations except the United Kingdom, the central government exercises a high degree of control over certain aspects of the educational system. These countries have ministries of education, which decide educational policy. But the ministries transfer some responsibilities to local authorities. In the United Kingdom, the national government shares control of the educational system with local authorities.

Financial support. In every nation, public funds are used to support education. Most countries that permit private schools also provide some financial support for such schools. In the Netherlands, public funds pay all the expenses of private schools. Other countries provide only partial support. Tuition fees and individual contributions pay the rest of the expenses of private schools.

Nations provide public funds for education in various ways. In general, two methods are used. (1) In most countries, including almost all heavily populated ones, the national government shares the cost of education with other levels of government, such as states, provinces, or cities. In many of these countries, such as Belgium, France, and Italy, the national government supplies most of the funds. In others, including China and India, the funds come mainly from lower levels of government. (2) In some countries, the national government pays all public education costs. These countries include Iran, New Zealand, and Thailand.

Many countries obtain additional funds for public education from tuition fees, voluntary contributions, and other private sources. Some developing nations receive foreign aid for education.

Some nations provide free education at every level. In the United Kingdom, for example, students may have all their educational and living expenses paid until they have completed their higher education. But only highly qualified students receive this privilege.

Learning and teaching

Educating people requires the dual activities of learning and teaching. Ideally, teaching should result in increased opportunities for learning. This section discusses how the two activities take place.

How people learn. There is no complete agreement among scientists and educators on the nature of human learning. But certain ideas are generally accepted. Learning theories are based largely on findings of modern psychology. Most theories for how people are able to learn things fall into three main groups.

One group of psychologists believes that people learn new things by forming habits. This group emphasizes *stimulus-response relationships.* They say that when we learn, we connect a *stimulus* (something that causes action) and a response that did not exist before, thus forming a habit. Habits can range from the simplest ones to the complex ones that are involved in learning how to do new things. These psychologists believe that when we experience a new problem, we use appropriate responses learned from past experience to solve it. If this procedure does not lead to the solution, we use a *trial-and-error approach,* trying many possible solutions before finding the right one. We use one response after another until we solve the problem. The stimulus-response approach has been used to explain and modify bad habits. For example, when a person is irrationally afraid of dogs, methods called *behavior modification,* or learning how to behave in a different way, can be used to replace the fear with a more relaxed response.

A second group of psychologists stresses *cognition* (the act of knowing) above the importance of forming habits. These experts feel that experiments involving *conditioning* (the shaping of behavior) are limited. They feel that these experiments cannot explain such complex learning as understanding concepts and ideas. Instead, the cognitive approach emphasizes the importance of the learner's discovering and perceiving new relationships and achieving insight and understanding.

A third group of psychologists has developed *humanistic theories.* According to these theories, much human learning results from the need to express creativity. Almost any activity, including athletics, business dealings, and homemaking, can serve as a creative outlet. The psychologists in this group believe that each person must become involved in challenging activities—and must do reasonably well at them—to have a satisfying life. The individual gains a sense of control, growth, and knowledge from such activities. For learning to occur, people must feel free to make their own decisions. They also must feel worthy, relatively free from anxiety, self-respecting, and respected by others. Under these conditions, their own inner drives will lead them to learn. Some kinds of group therapy try to provide an accepting, supporting environment. Such an environment is intended to increase people's awareness of their own thoughts and of the world around them.

Learning involves changes in the nervous system. Scientists are trying to discover the processes that take place in the brain to produce learning. Such research may lead to a *physiological* theory of learning—that is, a theory involving bodily processes.

How teachers guide learning. The teacher's main task is to create conditions that will encourage and stim-

Chicago Botanic Garden

Learning by doing is an important educational method. These children are learning how plants grow by caring for flowers at a botanical garden.

ulate learning. Teachers must help students develop their own initiative and ability to think critically. Good teachers guide students in seeking important knowledge and analyzing possible solutions to meaningful problems. They also help students understand important values involved in dealing with problems. Teachers use a variety of methods to achieve the desired learning goals. They also use such teaching aids as books, models, audio-visual materials, computers, and field trips.

Good teachers are well educated, know their subject, and understand their students. They are familiar with the principles of education, the psychology of human development, and the theories of learning.

Theories of teaching have not been as fully developed as have theories of learning. Many educators feel that a theory of learning also provides sufficient guidelines for teaching. Most teachers probably combine behavior modification, cognitive, and humanistic teaching principles. Many teachers do not consciously follow any theory, but rather depend on experience and intuition to guide them. See **Teaching**.

History

The first major milestone in the history of education occurred in prehistoric times with the development of language. Language enabled people to communicate more precisely than they could by signs and gestures. But early people had only a spoken language. They had no system of writing or numbering and no schools.

Young people in prehistoric societies were educated through *apprenticeship, imitation,* and *rituals* (ceremonies). Through apprenticeship, a young person learned, for example, how to build a shelter by working with an older, experienced master builder. Through imitation, young people acquired the language and customs of their parents and other adults in their society. Through the performance of rituals, they learned about the meaning of life and the ties that bound them to their group. The rituals consisted of dancing or other activities. They were performed at times of emotional stress, such as death, warfare, or drought. The rituals usually involved myths, which dealt with such things as the group's history and its gods and heroes.

Today, young people in all societies still learn through apprenticeship, imitation, and ritual. But as a society grows increasingly complicated, teachers and schools take on more and more responsibility for educating the young. The kind and amount of responsibility they assume vary from society to society. Teachers and schools never take over all educational responsibility, however.

The beginning of formal education. The Sumerians, who lived in the Tigris-Euphrates Valley, invented a system of writing about 3500 B.C. The Egyptians developed a writing system about 3000 B.C. Both systems included a method of writing numbers as well as language. The invention of writing was a major milestone in the history of education. It made possible the beginning of schools as we know them.

Before people developed writing, teachers had to repeat orally what was to be learned until the young had memorized it. A child could thus learn only what the teacher had memorized. But by teaching children to read, teachers could make available the knowledge of many people, not only their own. Yet reading and writing could not be learned while the child served as an apprentice, imitated the behavior of the elders, or took part in rituals. In addition, the first writing systems, which were a kind of picture writing, were awkward and difficult to master. As a result, special schools arose in which teachers taught reading, writing, and calculation.

About 3000 B.C., both the Sumerians and the Egyptians established schools to teach reading and writing. Temple priests taught many of the schools. Most students came from upper-class families. Only a small number of boys, and even fewer girls, were taught.

A student's training, which lasted from about the age of 5 to 17, was strict and monotonous. Students learned to write by copying the same literary selections again and again. They learned arithmetic by copying business accounts. Those who completed their education formed a separate social class called *scribes.* Scribes were hired for any task that required a knowledge of reading, writing, or arithmetic.

Civilization spread from Sumer and Egypt to the eastern shores of the Mediterranean Sea. Certain tribes in this region each spoke one of the closely related Semitic languages. About 1500 B.C., these tribes developed the world's first alphabet and so gave education another valuable tool. Alphabetic systems make writing easier than picture systems because they require far fewer symbols.

Certain Hebrew Semitic tribes developed a remarkably democratic educational system. Other educational systems had been designed mainly for the sons of upper-class families. But the Hebrews required boys of every social class to attend school. The Hebrew schools were religious schools conducted by priests called scribes. They taught boys to read the sacred writings of the Hebrew people, which were collected in a volume called the Torah. Hebrew girls did not attend school but were taught at home by their mothers.

Ancient Greek education. The Greeks made the greatest educational advances of ancient times. In fact, Western education today is based on the ancient Greek model. Greek civilization flourished from about 700 B.C. to about 330 B.C. During this period, Greek arts, philosophy, and science became foundations of Western thought and culture. Homer and other Greek writers created new forms of expression, including lyric and epic poetry. The greatest Greek poet was Homer. Homer composed two famous poems, the *Iliad* and the *Odyssey,* during the 700's B.C.

Ancient Greece was divided into *city-states,* independent states that consisted of a city and the region surrounding it. The educational system of each city-state aimed to produce good citizens. Athens and Sparta, two of the most powerful city-states, had different ideals of citizenship. In Sparta, citizens were judged largely by their political and military service. The government controlled education. Boys received physical and military training, but few learned to read or write. In Athens, unlike Sparta, citizens were judged more by the quality of their minds. Athens expected its citizens to develop their bodies and serve the state.

Athens made the greatest educational advances of any Greek city-state. But Athenian education was far from democratic. Education was limited to the sons of Athenian citizens. Less than half of all Athenians were citizens.

Slaves made up a large part of the Athenian population and were not considered worthy of an education.

Athenian boys started their education at about age 6. But they did not go to schools as we think of schools today. A trusted family slave took them from teacher to teacher, each of whom specialized in a certain subject or certain related subjects. Boys studied reading, writing, arithmetic, music, dancing, and gymnastics. As the boys advanced, they memorized the works of Homer and other Greek poets. Boys continued their elementary education until they were about 15 years old. From about ages 16 to 20, they attended a government-sponsored *gymnasium.* Gymnasiums trained young men to become citizen-soldiers. They emphasized such sports as running and wrestling and taught civic duty and the art of war. The schools held discussions to improve students' reasoning and speaking ability.

Some Athenian gymnasiums became centers of advanced learning. By the 400's B.C., advanced learning in Athens consisted of *philosophy* and *rhetoric.* Philosophy included the study of logic, mathematics, morals, and science. Rhetoric included the study of government, history, and public speaking.

During the 400's and 300's B.C., Athens produced such great philosophers and teachers as Aristotle, Plato, and Socrates. About 387 B.C., Plato founded a school of philosophy that became known as the Academy. Some scholars believe the Academy was the world's first university. Aristotle founded a similar school called the Lyceum in 335 B.C.

Most young Athenian women received no formal education. They mainly learned domestic skills from their mothers—that is, how to prepare food, make clothing, and care for infants. Some women, however, belonged to religious organizations through which they developed skills in music, poetry, and dancing.

Greece, like other countries in ancient times, had many somewhat secret religious groups that carried on educational activities. Even Plato's Academy and Aristotle's Lyceum were rather like religious brotherhoods united by sacred oaths and religious ceremonies. Some occupational organizations also had a religious and educational function. For example, medical science developed among a few families who joined together in a secret religious society to educate their children in the study of medicine.

In these religious and occupational groups—as in all areas of Greek life—young males associated closely with adult men. In fact, the Greeks believed a young man could learn to accept himself and discover his role in the community only by taking part in the total life of the community. In Sparta, for example, boys, young men, and adult males all ate in community dining rooms. The entire adult group was considered to be the parents and teachers of all the city's young.

The Greeks strongly believed that a boy could best learn what he is and should try to become by imitating an older, ideal model. For this reason, every young Greek male became the companion of an older citizen. In most cases, this person was a friend of the boy's father or a relative. The Greeks hoped that a strong love would develop between the two. As a result, the younger male would want to imitate his companion and in so doing take on his virtues.

Ancient Roman education. After about 600 B.C., a high civilization began to develop in Rome. By about 100 B.C., the Romans had built the most extensive educational system to that time. Their system was patterned after that of ancient Athens. But unlike the Athenians, the Romans provided schooling for girls as well as boys. The children of wealthy citizens were taught by a *ludus* (introductory teacher) from about the age of 7 to 10. These children learned to read and write both Greek and their native language, Latin. Girls received only an elementary education. Boys from about 10 to 14 years old attended a secondary school run by a *grammaticus* (teacher of grammar). In secondary school, the boys continued their study of Greek and Latin grammar and literature. The Romans also established institutions of higher learning. These institutions were schools of rhetoric, which prepared young men for careers in law and government.

Between 100 B.C. and A.D. 100, Roman poets, historians, and orators created a written literature that held the sacred myths and beliefs of the Roman people. The greatest poet was Virgil. His epic poem, the *Aeneid,* became as important to the Romans as the epic poems the *Iliad* and the *Odyssey* had been to the Greeks. In fact, Virgil modeled the *Aeneid* on the *Iliad* and the *Odyssey.* Other important writers included the poets Horace and Ovid, the historians Tacitus and Caesar, and the orator and statesman Cicero. The Latin writings of these men, along with the works of Greek scholars and poets, became the basic curriculum throughout most of the history of education in the Western world.

Cicero has been particularly important in the history of Western education. Not only have his essays been widely read and studied, but also his theories of education have long influenced Western views on education. In addition, Cicero's philosophical ideas helped many highly educated Romans convert from their old religion to Christianity.

Although the Romans adopted many Greek educational traditions, they surpassed the Greeks in some fields. In agriculture, engineering, and law, for example, the Romans not only developed greater knowledge and experience, but they also put this knowledge into writing. Education in these fields remained largely a matter of apprenticeship, but written information and formal instruction played a vital part in the apprenticeship.

By about A.D. 200, Roman culture had spread over much of the Western world, and most educated people thought of themselves as Roman citizens. Indeed, the basic issue of teachers and philosophers had become "What does it mean to be a good Roman?"

Religion and early Western education. The religion of the Hebrew people, Judaism, became the parent religion of two other religions—Christianity and Islam. Much of the Hebrews' holy writing became the Old Testament in the Christian Bible. The New Testament, which deals with Jesus Christ and His followers, was added as further revelation of God's truth. The Muslims, whose religion is Islam, incorporated much of the Bible in their holy book, the Quran. All three religions thus have a shared origin as well as sacred books and other things in common. These common elements had important effects on early Western education.

The followers of each of the three religions believed (1) that one God created and rules the universe; (2) that

Miniature from a French manuscript by an unknown artist, Bibliotheque Nationale, Paris

The University of Paris became known throughout Europe in the Middle Ages for its faculty of famous scholars and teachers.

He permits no competition; (3) that He has revealed Himself to people; (4) that from the sacred, written record of this revelation, people find their ultimate meaning and basic duty; and (5) that God's chosen people have a sacred mission. Hebrews, Christians, and Muslims each developed educational systems that carefully taught these beliefs to the young . Young people were also taught that their particular religious group was spiritually superior to other groups.

Hebrews, Christians, and Muslims each developed a class of scholars who interpreted their group's sacred writings and explored how those writings could be applied in different conditions, times, and places. Each group tended to view itself as a chosen people. As a result, the groups' educational systems tended to emphasize a sharp line between "believers" and "nonbelievers." Christians and Muslims felt an especially strong need to convert nonbelievers, usually through missionary work but sometimes through warfare.

This missionary impulse led Christians to spread their educational system throughout northern Europe during the first few centuries of the Christian era. It also led them to try to convert the peoples of North and South America, Africa, Asia, and the Pacific Islands from the 1400's to the 1900's. Meanwhile, the Muslims spread their culture from Indonesia in the east to Spain in the west. In this way, Christians and Muslims introduced formal schooling to many cultures.

Christian and Muslim missionaries also went to India and China. But the Indians and Chinese already had possessed for many centuries sacred books, written traditions, and formal schooling. The Chinese and Indians felt that the Christian and Muslim missionaries represented cultures that were spiritually and intellectually shallow.

Christian education in the Middle Ages. The Christian church played an important part in shaping European education during the Middle Ages, which lasted from the fall of the Roman Empire in the A.D. 400's to the 1500's. Before the fall of Rome, peoples in western and southern Europe had already begun to shift their loyalty from the Roman state to the Christian church. In fact, the basic issue of teachers and philosophers had now become "What does it mean to be a good Christian?" rather than "What does it mean to be a good Roman?"

Christian parents were expected to know the laws and beliefs of Christianity and to teach them to their children. Religious authorities controlled most formal education. But for many centuries, only those people who were destined for a religious vocation received such schooling. Some youngsters were educated by their local priests or in the bishop's household. Others were taught in monastery or cathedral schools.

In the monastery and cathedral schools, students studied such subjects as church music, theology, and Latin, the official language of the Western church. They were also taught subjects similar to those taught in ancient Greece and Rome. These subjects were divided into two groups, which together were known as the *seven liberal arts*. The first group, called the *trivium,* consisted of grammar, rhetoric, and logic. The second group, called the *quadrivium,* consisted of arithmetic, geometry, astronomy, and harmonics.

Many young people who did not receive formal schooling became apprentices to skilled masters and learned a trade. Young men learned the arts and values of *chivalry* (the qualities of an ideal knight), which prepared them for military or government careers. Business people, craftworkers, merchants, and other groups formed professional societies called *guilds*. The guilds ranked among the leading educational institutions of the Middle Ages. They provided informal education in technical and social matters for guild members as well as some formal education for the members' children.

The rise of the universities. The first modern universities developed in Europe during the 1100's. The universities did not originate as places or as groups of buildings. They began instead as collections of scholars organized into corporations with certain privileges and responsibilities. In fact, the word *university* comes from the Latin *universitas,* the term for *corporation* or *guild* in the Middle Ages.

Most European universities were patterned after one of two models. The model for the majority of universities in the north was the University of Paris, which became the largest and most famous university in Europe during the 1200's. Most northern European universities developed from teachers' guilds at cathedral schools. The guilds charged a fee to train students and to grant degrees. The universities that developed from these guilds were run by corporations of teachers. Most of them specialized in liberal arts and theology.

The universities gradually received certain privileges from religious and governmental authorities. These priv-

ileges included the right to admit students to the universities. Within limits, the universities could also try their own members for *heresy*—that is, for holding or teaching ideas that conflicted with those of the church. The university scholars thus had greater freedom of thought and expression than other people had.

Most southern European universities were modeled after the University of Bologna in Italy, which came into existence about 1100. The universities began as students' guilds, and most of their students were mature and successful professional people. The guilds hired the professors and set the working conditions. These conditions included punishing teachers for being absent or tardy. Most southern European universities were nonreligious in origin, and most of them specialized in law or medicine.

During the Middle Ages, the universities did not require students to have completed primary and secondary education to be admitted. Some students had years of previous schooling, but others had not. As late as the 1500's, a student might go to several universities before learning to read. For example, a youngster might begin attending universities at the age of 10, wandering from one to another. In each university, students were taught orally. They might not learn to read and write until their late teens.

By 1500, nearly 80 universities had been founded in Europe. Some survived a short time. Others still exist. They include Cambridge and Oxford universities in England; the universities of Montpellier, Paris, and Toulouse in France; Heidelberg in Germany; Bologna, Florence, Naples, Padua, Rome, and Siena in Italy; and Salamanca in Spain.

The Renaissance was a period in European history when many people showed a renewed interest in the world and a growing spirit of individuality and independence. It began in Italy during the 1300's and spread across Europe during the 1400's and 1500's.

During the Renaissance, *classical humanist* scholars stressed the human experience of the ancient Greeks and Romans, rather than the religious experience of the Middle Ages. The classical humanists were deeply interested in the Greek and Roman classics. Scholars of the Middle Ages had valued the writings of a few Greek and Roman authors because their logic and rhetoric could be used to support Christian teachings. The humanists of the Renaissance valued the Greek and Roman classics for what they said about civilized life as well as for their logic and rhetoric.

The humanists, like the ancient Athenians, believed that the main purpose of education was to train well-rounded, cultured citizens. They considered the ancient Greek gymnasium the ideal type of school. During the 1300's and 1400's, schools patterned after the Greek gymnasiums arose in many parts of Europe. They admitted mostly the sons of upper-class families, who came to learn Greek and Latin and the works of the ancient writers. Because there were few textbooks, students had to memorize texts read to them in class. They also learned how to behave like gentlemen and took part in body-building sports.

In time, these schools modeled after the Greek gymnasium developed into the European *secondary school,* which was designed for upper-class boys and offered a liberal arts program based on Greek and Latin sources. These secondary schools had different names in different countries. They were called *gymnasia* in Germany, *lycées* and *collèges* in France, and *grammar schools* in England. Boys entered school between the ages of 6 and 9. Until the 1800's, secondary schools provided the only formal education for most upper-class European boys, except for those who attended the universities.

Children of the lower classes attended primary school, where they learned reading and writing in the *vernacular* (local language), arithmetic, history, literature, and geography. In European history, the primary school was an alternative to the secondary school. Usually, primary school graduates could not enter a secondary school or a university. Primary schools began to appear in Europe in the 1500's, but universal education did not begin in Europe until the 1800's.

During the Renaissance, many classical humanists produced literary works in the vernacular as well as in Greek and Latin. In the 1300's, for example, the great Italian poet Petrarch wrote more than 400 poems in Italian. Geoffrey Chaucer of England wrote his masterpiece, *The Canterbury Tales,* in English. Some scholars translated the Latin Bible into vernacular tongues.

The vernacular writings had only a small audience, however. Relatively few people could read. In addition, books were scarce and expensive because they had to be laboriously written by hand. Only a few people could arrange to borrow one or hire a scribe to copy it. Even university students had to memorize a book from hearing it read by the professor, whose "lectures" consisted mainly of slowly reading aloud the basic text and commenting on it. Thus, some students could get a university education without knowing how to read or write. They memorized what they heard, and their teachers tested them orally.

The invention of printing as we know it became another great milestone in the history of education. About 1440, a German goldsmith named Johannes Gutenberg invented movable type in Europe. He also devised a special press to print from his movable type. Almost immediately, large numbers of low-cost books and pamphlets became available. As a result, thousands of people wanted to learn to read and write. In addition, the great quantity and variety of printed matter enabled people not only to learn without an instructor but also to acquire the knowledge to become teachers themselves. Moreover, printing spread knowledge faster than ever before. People could thus quickly learn about new theories, experiments, and discoveries.

The Reformation. The invention of printing occurred at a time when the Roman Catholic Church was torn by conflict. This conflict led to the Reformation, the religious movement of the 1500's that gave birth to Protestantism. In the 1300's and 1400's, certain reformers had begun to question some teachings of the church and to press for changes. One of their main beliefs was that all Christians should be able to read the Bible in their own language. But until the invention of printing, most Europeans knew little about reformers' arguments. By the 1500's, pamphlets criticizing the church had become widespread throughout the Christian world. In addition, printing made available relatively inexpensive Bibles in vernacular translations. The argument that every Chris-

tian should learn to read the Bible thus became practical for the first time.

During the 1500's, Protestant sections of Europe, including parts of Germany and Switzerland, established elementary schools to teach the children of common citizens to read the Bible in their native language. These vernacular schools also taught Christian morality and beliefs.

Meanwhile, the Roman Catholic Church expanded its educational activities as part of the reform movement called the Counter Reformation. Several Catholic religious orders established vernacular schools for Catholic children. The number of secondary schools also expanded rapidly during the Reformation in both Protestant and Catholic regions of Europe.

The Age of Reason, a period of great intellectual activity, began in the 1600's and lasted until the late 1700's. During this period, scientists believed that, through reasoning and experimentation, they could discover the laws by which nature operates. This idea led to the development of the modern scientific method and created a scientific revolution.

To carry out experiments, scientists needed new tools. Inventors met these needs with such instruments as the microscope, sextant, slide rule, and chronometer. Aided by the new instruments, scientists advanced rapidly. Discoveries by the English scientist Sir Isaac Newton revolutionized astronomy. Robert Boyle of Ireland, Antoine Lavoisier of France, and Joseph Priestley of England founded modern chemistry. France's René Descartes invented analytic geometry. The English physician William Harvey discovered how blood circulates in the human body.

The advance of science affected education. Science began to be taught in the schools, though it did not become a major subject in elementary and secondary schools until the mid-1800's. By the late 1700's, however, the demand for an extensive scientific curriculum in universities had become overwhelming.

As knowledge of natural science expanded, such philosophers as Descartes and England's Thomas Hobbes and John Locke began to urge the development of a social science. These thinkers suggested that human societies could be viewed as "universes" that were understandable through scientific investigations like those used to study the physical world. These philosophers also believed that the reasons people behaved as they did could also be understood through science.

Today, educators discuss educational problems in the language of sociology and psychology and try to solve these problems through experimentation. These techniques can be traced back to the ideas of the early social scientists.

The scientific revolution also affected education by changing the nature of *technology.* Technology refers to all the ways people use their inventions and discoveries to satisfy their needs and desires. People can master a technology that is not based on science by serving an apprenticeship. But a technology based on science requires formal schooling. By assisting their parents, for example, children could learn to plow, sow, and reap in a traditional manner. But with the arrival of advanced farm machinery and scientific farming methods, agriculture came to depend on people trained in science.

By the late 1700's, the technologies of textile manufacturing, transportation, and many other fields had become increasingly dependent on highly educated engineers and scientists. Trade and technical schools arose in many parts of Europe. In the United States, such leaders as Benjamin Franklin and Thomas Jefferson called for the addition of "useful" subjects to the school curriculum. By "useful," they meant science courses that could be applied to technology.

The rise of universal public schools. By the late 1700's, the nation, rather than the church, had become the chief symbol that united the people of several European countries as well as the people of the United States. As people shifted their greater loyalty to their nation, the church's control over formal schooling declined while that of the state increased.

Modern nationalism—the idea that a person owes primary allegiance to the state—first reached its fullest expression in France during and after the French Revolution (1789-1799). By 1833, the French government had taken control of all the nation's schools. The Kingdom of Prussia, a German-speaking state, also developed a national school system in the early 1800's. Through its schools, Prussia made nationalism the highest ideal of German-speaking peoples. When its king became the first emperor of a united Germany in 1871, many people believed the Prussian system of nationalistic schools had contributed to the state's rise to power. As a result, other nations began to follow Prussia's lead.

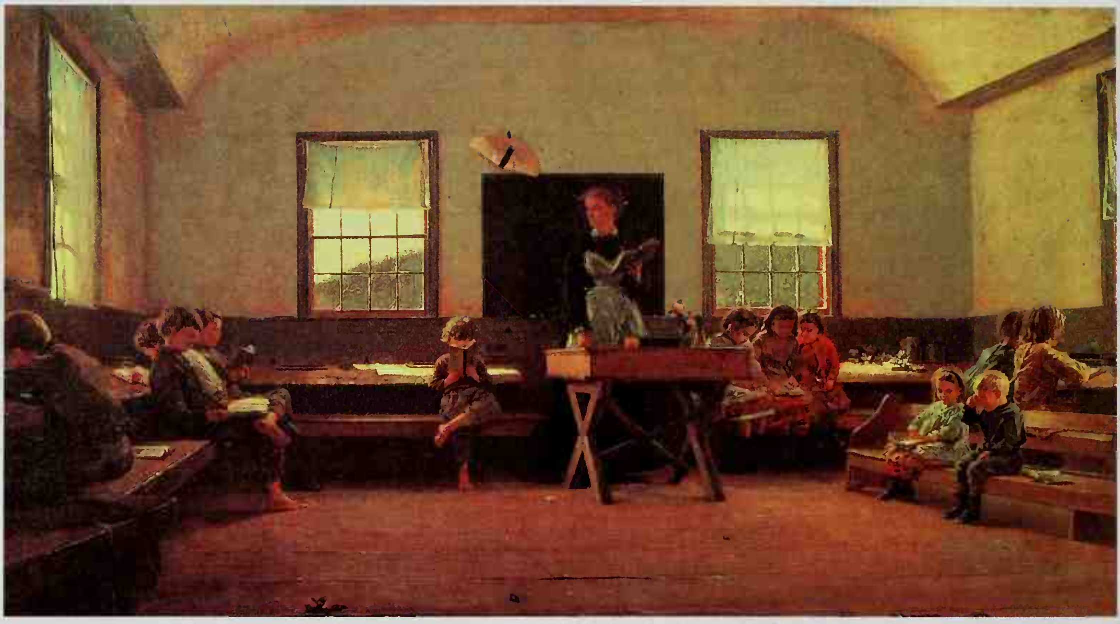
By the early 1900's, public elementary education was free and compulsory in most European countries. Some countries also provided free secondary schooling. Vocational and technical education made great strides in Europe during the 1900's. But today, many European countries also stress general education at the secondary level. Many nations added *infant schools* (nursery schools) to their systems in the mid-1900's.

Education today. Today, the ideal of free, compulsory education has taken root throughout the world. Almost all countries have adopted the plan of educational organization used in the West—that is, the division into early childhood, elementary, secondary, and higher education. Most developing nations have established professional teacher-training programs patterned after those of the Western nations. The Western nations, in turn, have borrowed from the educational traditions of China, India, and other non-Western civilizations.

Development of Canadian education. From the early 1600's to the mid-1700's, the Catholic Church controlled most education in Canada. Most colonists of this period were French Catholics who lived in the St. Lawrence River Valley. They set up French-language elementary schools taught mainly by parish priests and members of religious orders. The Jesuits established a few classical secondary schools for boys. One of these, the Seminary of Quebec, was founded in 1663. It was named Laval University in 1852.

In 1763, the United Kingdom gained control of all Canada. After that date, English settlers established many English-language schools. These included Protestant elementary and secondary schools for upper-class boys patterned after the English grammar school.

After about 1800, the British tried to set up a common school system for French Catholics and English Protes-



The Country School (1871), an oil painting on canvas by Winslow Homer; the St. Louis Art Museum

One-room country schools were common in the United States in the 1800's. One teacher taught all the grades, *shown here*. Teaching methods of the 1800's stressed memorization and discipline.

tants in Quebec. But Catholic opposition killed the effort. In 1846, a law established separate Protestant and Catholic school systems for Quebec. During the 1850's and 1860's, Ontario, which was largely Protestant, developed an educational system in which taxes supported both public and religious schools.

The British North America Act, passed in 1867, brought about the federation of the Canadian provinces. The act left education under provincial control. It also guaranteed public support for religious schools in the provinces that had provided such support before 1867. These included the heavily populated provinces of Ontario and Quebec.

During the late 1800's, elementary education became free and compulsory throughout Canada. Canada's first publicly controlled, coeducational high school opened in Ontario in 1871. It served as a model for many high schools in English-speaking parts of Canada.

Development of U.S. education. Most colonists who came to America set up the kinds of schools they had known in Europe. Protestants and Roman Catholics established and supported their own schools. Most were elementary schools designed to teach reading, writing, and religion. School attendance was not compulsory in the American Colonies. Only about 1 child out of 10 went to school. Many children learned trades by becoming apprentices. The children of wealthier colonists studied under tutors or were sent to tuition schools or to schools in England.

In 1642, the Massachusetts Bay Colony, the largest New England colony, passed a law requiring parents to teach their children to read. In 1647, Massachusetts passed the first law in America requiring communities to establish public schools. The law required every town with at least 50 families to start an elementary school, and every town of 100 families or more to have a Latin grammar school. Like other colonial schools, these town schools taught religion. But unlike other schools in the colonies, they were partially supported by public funds. The elementary schools were open to all children. The grammar schools taught mainly boys preparing for college. The Boston Latin School, which opened in 1635, was the first Latin grammar school—and the first secondary school of any kind—in the American Colonies. In 1636, Massachusetts founded Harvard College, the first institution of higher learning in the colonies. By the early 1800's, the school had become Harvard University.

The 1700's. Secondary schools called *academies* were started in many of the colonies during the 1700's. Academies offered more practical courses than did Latin grammar schools. A student could take such subjects as bookkeeping and navigation in addition to religion and liberal arts courses. Most academies were private schools supported by tuition fees. Some admitted girls, and some were established for girls only.

When the Revolutionary War in America ended in 1783, the newly independent nation called the United States had 18 institutions of higher learning. Several were partially state supported and controlled. In 1785, Georgia chartered the first state university, but it did not open until 1801. In 1795, North Carolina University (now the University of North Carolina at Chapel Hill) became the first state university to hold classes.

Unification through education. After the Revolutionary War, many Americans were concerned with unifying the nation. Attempts to promote unity had two important effects on education: (1) the development of standardized textbooks and (2) the building of state public school systems.

During the 1700's and early 1800's, a number of edu-

cators produced books designed specifically for Americans. Noah Webster's famous "Blue-Backed Speller" helped standardize spelling and pronunciation in the United States. Millions of elementary school students used illustrated reading books published by William H. McGuffey. These "McGuffey Readers" taught patriotism and helped form literary tastes in the United States.

Early American educators also emphasized that good Americans were deeply religious—and were preferably Protestants. Good Americans were also honest, thrifty, hard working, and courageous. In trying to develop an idealized view of Americans, the early educators often described other people as lacking in these traits. This tendency was reflected in the textbooks developed for school use. Most American authors saw the English, Scottish, German, and Swiss people as like themselves and thus highly admirable. But people whose way of life differed from their own were described unfavorably. Authors often described Spaniards, for example, as cruel and lazy. They said the American Indians—though noble and loyal to their own group—were savages who needed to be civilized. Many peoples throughout history have used their schools in this way to give children a sense of their nation's greatness.

The textbooks and other teaching materials were thus designed to unify the American people. But in the early 1800's, an increasing number of people came to believe that something more was needed to give Americans common goals and a sense of national unity. They felt the answer lay in public education and proposed that each state set up a system of free, compulsory, tax-supported schools. They wanted the schools to be free of religious control but devoted to building character and teaching patriotism.

Certain religious groups, especially Roman Catholics and Lutherans, disliked some of the principles taught in public schools. As a result, they maintained and controlled alternate schools. Some people, particularly the wealthy, disliked the fact that public schools tended to equalize everyone. They continued to send their children to private schools. But for generations, immigrants from many countries and of many religions found public schools an entry into the mainstream of American life.

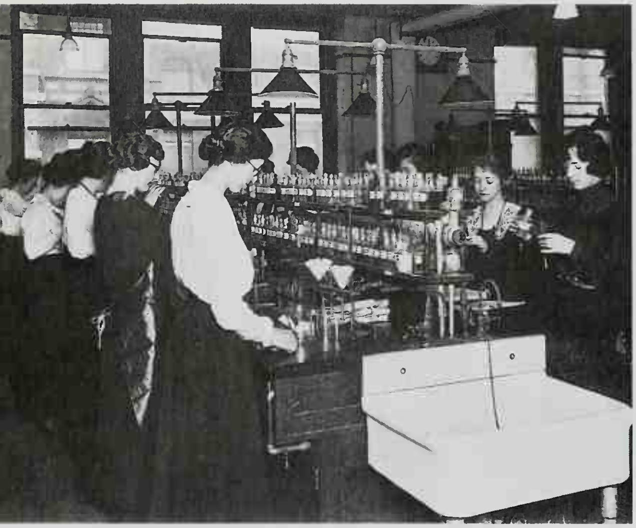
Advances in public education. In 1837, Massachusetts established a state board of education to coordinate its public school system. This board became a model for boards in other states. The first secretary of the Massachusetts board, the educator Horace Mann, did much to strengthen education in the state. Under his leadership, Massachusetts began the nation's first public *normal school* (teacher-training school) in 1839. In 1852, the Massachusetts legislature passed the first compulsory school-attendance law in the United States. By the end of the 1800's, 31 of the 45 states had school-attendance laws. By 1918, every state had one.

Boston opened the nation's first public high school in 1821. But some people believed that the use of public funds to support secondary schools was illegal. This question was largely settled by a Michigan Supreme Court decision in 1874. The court ruled that local governments could use tax money to support secondary schools as well as elementary schools.

Advances in higher education. Higher education also made many advances during the 1800's. Churches and other private organizations founded several hundred small liberal arts colleges in the 1800's. In an 1819 decision, the Supreme Court of the United States had prohibited the states from taking over private colleges (see **Dartmouth College case**). In 1833, Oberlin Collegiate Institute (now Oberlin College) in Ohio became the first coeducational college in the United States. In 1862, Congress passed the Morrill, or Land-Grant, Act, which gave vast areas of federal land to the states. The act required each state to sell the land and use the proceeds to start agricultural and technical colleges. In 1890, Congress passed the Second Morrill Act. This act withheld grants from states that denied admission to land-grant schools on the basis of race. A state could receive grants, however, if it provided separate schools for blacks. As a

Important dates in U.S. education

1635	The Boston Latin School, the first secondary school in the American Colonies, began classes.
1636	Massachusetts chartered Harvard College, the first college in the American Colonies.
1642	Massachusetts passed an education law requiring parents to teach their children to read.
1647	Massachusetts became the first American colony to require establishment of public elementary and secondary schools.
1785	Georgia chartered the first state university.
1795	The University of North Carolina became the first state university to hold classes.
1819	The Supreme Court of the United States ruled that a state cannot take over a private college without its permission.
1833	Oberlin Collegiate Institute (now Oberlin College) became the first coeducational college in the Unite States.
1852	Massachusetts passed the first compulsory school-attendance law in the United States.
1862	The Morrill Act gave federal land to support state agricultural and technical colleges.
1874	The Michigan Supreme Court ruled that taxes could be collected to support public high schools.
1917	Congress passed the Smith-Hughes Act, the first act to provide federal funds for vocational education below the college level.
1944	Congress passed the first GI Bill, granting funds to veterans to continue their education.
1954	The Supreme Court of the United States ruled that public schools segregated by race are unequal and therefore unconstitutional.
1965	Congress passed the Elementary and Secondary Education Act to aid local schools and to improve the education of children from low-income families.
1972	Congress passed the Education Amendments Act, which grants funds to almost every institution of higher learning to use as it wishes.
1978	The U.S. Supreme Court ruled that college and university admission programs may not use specific quotas to achieve racial balance. But they may give special consideration to members of minority groups.
1979	Congress established the U.S. Department of Education.
1983	The National Commission on Excellence in Education reported in *A Nation at Risk* that U.S. students lagged far behind students in many other industrialized nations.
1991	Minnesota enacted the first state law authorizing charter schools.
1994	Michigan became the first state to sharply reduce the use of property taxes in the financing of its public schools.
2000	The Supreme Court of the United States ruled that students may not lead group prayers at public school football games.



Brown Bros.

Higher education for women became available during the 1830's in coeducational colleges. These students attended Vassar College in the early 1900's, when it was a women's college.

Photograph from *Community Schools* by Elsie Ripley Clapp. © The Viking Press, Inc. (Morris Library, Southern Illinois University)

Progressive education rejected the formal teaching methods of the 1800's. Pupils at this progressive school of the 1930's learned about community life by building a miniature town.

result, many Southern States established black land-grant colleges and universities.

New theories of education. The early 1900's brought far-reaching changes to education in the United States. A number of educators in the 1800's paved the way for these reforms. Margaretha Schurz, the wife of political leader Carl Schurz, opened the nation's first private kindergarten in 1856 in Watertown, Wisconsin. William T. Harris helped establish the nation's first public kindergarten in St. Louis, Missouri, in 1873. Kindergartens used play and creative activities as teaching methods. Francis W. Parker, an Illinois educator, adopted these methods for use in elementary schools. The teaching methods used in many schools in the 1800's stressed memorization and discipline. Parker believed education's chief goal should be the complete development of every child, and more freedom was needed to achieve this goal. Parker and other educators broadened elementary school courses by adding such subjects as geography, history, and science. In Chicago, he established one of the first parent-teacher associations that met regularly to discuss education.

The new child-centered theories of education influenced many educators who felt that the schools had not kept up with changes in society. These educators proposed that teachers adopt such methods as field trips, group discussions, and creative activities to help prepare children for life in a democracy. John Dewey and William H. Kilpatrick were two of the principal supporters of such ideas, which became known as *progressive education.* See **Progressive education**.

Joliet Junior College, the nation's oldest junior college, opened in Joliet, Illinois, in 1901. About 1910, several U.S. cities built the first junior high schools. Vocational education developed rapidly after Congress passed the Smith-Hughes Act in 1917. The act granted the states federal funds for vocational education in agriculture, home economics, and industrial arts.

The Great Depression and World War II. A decline in the U.S. birth rate during the 1920's contributed to a decrease in elementary school enrollments during the Great Depression of the 1930's, a worldwide economic slump. But high school and college enrollments climbed as many young people unable to get jobs continued their education.

School enrollments dropped at all levels after the United States entered World War II in 1941. Many high school and college students enlisted in the armed forces or were drafted. Many others went to work in war industries. A greatly increased birth rate in the years immediately following World War II led to a rapid rise in elementary school enrollments in the 1950's.

Since the mid-1900's, the U.S. educational system has experienced a number of changes. Larger school enrollments after World War II created a need for more school buildings, and inflation increased the cost of constructing and operating schools. Teachers' organizations became more militant as they bargained for improved benefits for their members. Teacher militancy led to many strikes. Partly as a result of these efforts, the average annual salary of U.S. schoolteachers increased by more than 70 percent from 1960 to 1970.

The federal government greatly increased its financial aid to education during the mid-1900's. After World War II, for example, Congress began granting federal funds to armed forces veterans to attend colleges and other schools. This program helped more than 10 million veterans continue their education after leaving service.

The Elementary and Secondary Education Act, passed by Congress in 1965, furnished local school districts with funds to help educate children from low-income families. In 1981, the act became known as the Educational Consolidation and Improvement Act. The federal government provided large sums of money for higher education through the National Defense Education Act of 1958, the Higher Education Facilities Act of 1963, the

Higher Education Act of 1965, and the Education Amendments Act of 1972.

In the late 1980's and early 1990's, reformers began experimenting with a number of new educational models. In 1991, American business leaders established New American Schools, a nonprofit organization that helps public schools carry out reforms. Numerous school-reform efforts, several of which were supported by New American Schools, produced dramatic improvements in student performance. Some of the better-known of these reform programs were Accelerated Schools, which encourages educators to provide more challenges to struggling students instead of teaching the same material repeatedly; and Success for All, an elementary-school reading program developed at Johns Hopkins University. Others were Roots and Wings, a program in mathematics, science, and social studies; the Audrey Cohen College System of Education, which calls for learning to center around meaningful activities that contribute to the community; and the Modern Red Schoolhouse, which blends challenging classes with technology, community help, and teacher training.

By the beginning of the 2000's, public elementary and secondary schools in the United States enrolled more pupils than at any time in the nation's history. School districts struggled to build enough schools to meet the twin demands of increased enrollment and smaller class size. To meet these needs, some districts shifted to year-round school calendars where schools are open 12 months a year. Students are enrolled in different tracks, and one track is on vacation at any given time. If the school uses three tracks, it can increase its student capacity by 50 percent.

In 2001, Congress passed legislation that expanded the role of the federal government in public education. The law, called the No Child Left Behind Act, increased federal aid for public schools and introduced new federal requirements for student testing.

Other important developments in U.S. education include efforts to guarantee equal educational opportunities to minority groups and to provide public funds to parochial schools. The next section of this article discusses these and other recent developments.

Current issues in U.S. education

Educators, policymakers, and parents in the United States debate many issues in education. The major questions include what should be taught, how performance could be improved, what students should know, who should choose a child's school, who should teach, who should be educated, how schools should be run, and how education should be financed.

What should be taught? Through the years, the chief purposes of U.S. education have included (1) acquisition of knowledge, (2) intellectual discipline, (3) education for citizenship, (4) individual development, (5) vocational training, and (6) character education. Most American educators believe education should serve all these purposes. But some experts feel education should serve some purposes more than others. These people often support either *curriculum-based education* or *needs-based education.*

Curriculum-based education emphasizes the acquisition of knowledge and skills. It focuses on the study of such basic subjects as English and mathematics. Its supporters believe it provides all students with the knowledge they need to function in American society.

Curriculum-based education gained widespread support in the late 1950's. Progressive education had been popular in U.S. schools in the first half of the 1900's. In 1957, however, when the Soviet Union launched Sputnik 1, the world's first artificial satellite, numerous United States citizens became fearful that the Soviets had surpassed the United States in science and technology. In response to these concerns, many schools adopted a more rigorous curriculum that placed particular emphasis on mathematics and the physical sciences.

Needs-based education, like progressive education, stresses the total development of the individual. Students are encouraged to express their feelings and ideas and to study subjects that interest them. Needs-based education is intended to help children develop emotionally, physically, and socially as well as intellectually. It became popular during the 1960's, when educators began to focus on the special educational needs of poor, minority, and disabled students.

Supporters of needs-based education have started hundreds of schools outside the established public and private school systems. In the 1960's and 1970's, a number of individuals and groups started nontraditional, or alternative, schools, generally called *free schools.* Most were elementary schools, but some were for high school or college students. They were run by parents, volunteers, religious groups, or other private agencies.

Over the years, educators have tried to create a system that both supports individual development and teaches the knowledge and skills required by society. Needs-based and curriculum-based systems have often been combined. But average scores on standardized examinations for high school students fell during the late 1900's. Some test scores indicated a particular lack of understanding of science and mathematics. Various studies found that students were also performing poorly in geography, history, and literature.

How can performance be improved? In 1983, a federal group known as the National Commission on Excellence in Education called for major improvement at all levels of U.S. education. In its report, *A Nation at Risk* (1983), the group pointed out that American students lagged far behind students in many other industrialized countries. The commission criticized the low performance standards of U.S. schools for contributing directly to a rising illiteracy rate and to a growing need for on-the-job remedial education. The commission urged schools to establish a *core curriculum* of courses in English, mathematics, science, social studies, and computer science. The group also recommended longer school hours, more homework, and increased teacher salaries.

Average scores on standardized tests for high school students rose slightly in the early 1980's. Black and Hispanic students' scores showed the greatest improvement. Some people attributed the higher scores to the establishment of core curriculums, such as the one recommended by the National Commission on Excellence in Education. But many educators called for additional measures to help American students attain a consistently high level of achievement. Many educators and parents called for stricter measures against drug abuse and

for greater discipline in the classroom.

Studies published in the mid-1980's confirmed concerns that U.S. schools were still struggling. The National Governors' Association's report, *Time for Results: The Governors' 1991 Report on Education* (1986), stated that the continued poor performance of schools threatened the nation's economic future.

Student testing. Since 1969, a federally funded testing program called the National Assessment of Educational Progress (NAEP) has been collecting information about the skill and knowledge levels of U.S. students in various subjects. Results of the NAEP show that students in the 4th, 8th, and 11th grades have made relatively small gains in reading, math, and science over the years. The results also show that the gap between white children and African American and Hispanic children narrowed in the late 1900's.

Critics of the NAEP and other testing programs claim that national testing may not properly recognize local differences. Many people believe such testing may be unfair to students from lower social and economic groups or different cultural backgrounds.

When the performance of students in the United States is compared to that of children in other countries, children in the United States generally perform at lower levels. In the late 1990's, however, the gap between the top-performing countries and the United States narrowed in most areas of educational achievement.

Illiteracy. Education authorities have identified illiteracy as one of the greatest problems facing American education. Experts estimate that as many as a fifth of all adults in the United States are *functionally illiterate*—that is, unable to read and write well enough to meet the demands of American society. During the 1980's, schools began to experiment with different teaching methods and increased free time for reading in an effort to stimulate students' interest in reading. Some schools established adult reading centers to teach illiterate parents how to read and how to help their children develop good reading skills.

Accountability testing. During the late 1970's and the 1980's, many schools began using more aggressive approaches in efforts to improve education. One of the most popular means of upgrading education involved the development of *accountability systems.* Under an accountability system, teachers and schools are held responsible for students' progress. Successful accountability systems provide data about school performance over time using a consistent framework.

One of the most common ways of achieving school and teacher accountability is through frequent testing of student *competence* (ability). Such testing is designed to show whether the students have mastered specific skills. The federal No Child Left Behind Act of 2001 required annual state tests for children in grades 3 through 8. The legislation also included measures for identifying low-performing schools and for assisting students in those schools. Under the law, if a school consistently performs poorly, its students may receive funds for tutoring or for transportation to other public schools.

People who favor accountability systems believe such systems promote the effective teaching of basic skills. Many educators claim, however, that these systems fail to promote analytical or creative thinking.

What should students know? In the early 1990's, U.S. educators and policymakers began considering what a student should know at a particular grade level. Many critics of U.S. education suggested that a carefully developed national curriculum would answer this question. They believed it would also unite the nation's people through a common body of knowledge and serve as a basis for standards of academic performance.

The effort to define what students should know is part of a larger movement that focuses on *cultural literacy.* Cultural literacy refers to a person's knowing the basic information an individual needs to succeed in the modern world. It includes basic skills in such fields as computer science, economics, geography, and literature. Many supporters of the movement favor the development of a national curriculum and national testing. They believe, for example, that all students should read certain books considered important to understanding American culture and heritage.

Who should choose a child's school? Traditionally, children in the United States have been assigned a public school to attend. But some parents have chosen to send their children to private schools or public schools that offer special programs. Other parents choose to educate their children at home. Growing numbers of people support the idea that all parents should be able to choose their child's school.

Many school systems have established *magnet schools* as a way of encouraging families to send their children to specific schools beyond their normal school boundaries. These schools are called *magnets* because they are designed to attract students from many different social and cultural groups. A magnet school is a public school that offers special training in a particular field, such as engineering or the visual and performing arts. Students must apply for admission.

In magnet schools, parents work closely with educators and may help establish the schools' curriculum, admission requirements, performance standards, and other policies. As a result, a magnet school's curriculum tends to reflect the educational priorities of the community it serves. For example, in many parts of the United States, magnet schools specializing in bilingual education serve Hispanic American students.

Other forms of school choice include *open enrollment* and *vouchers.* Open enrollment allows parents to send their children to a public school in or outside their local district, provided that their choice does not interfere with desegregation plans. Some states allow open enrollment on a statewide basis. Other states offer open enrollment within districts.

Many people have proposed that school choices would be increased through a voucher system. Under this system, parents would receive a coupon that could be exchanged for schooling in any public school. In some instances, private schools would also be allowed to accept the vouchers. Voucher programs are being tested in Milwaukee and in Cleveland. In a number of other communities, national and local philanthropists have joined to provide privately funded vouchers for a small number of children to attend private schools or other public schools.

Vouchers are appealing in terms of allowing more choice of schools. Many people oppose them, however,

fearing that wealthy parents will enroll their children in the best, most expensive, private schools. As a result, poor families would have only limited school choices.

Some people think that parents should be able to choose from parochial and other private schools, as well as from special public schools. They claim that having options enables poor parents to send their children to better schools and improves schools by making them compete for students and funds. Many opponents claim that it may weaken public education and increase segregation. Others feel such programs are unconstitutional because public funds help pay for education offered by religious organizations. But in 2002, the U.S. Supreme Court ruled that such programs are constitutional.

Who should teach? Studies conducted in the late 1970's and early 1980's found that some teachers lacked a basic knowledge of the subjects they were teaching. The studies led to sharp criticism of teacher-training programs at American universities and colleges. Many people felt that these programs did not require students who majored in education to master the subject that they wished to teach. To improve their teacher-training programs, some universities and colleges raised the standards for admission to the programs. They also required students to select a major other than education.

Teachers and other educators opposed these attacks on teacher performance. They pointed out that the majority of teachers are dedicated and well trained. Many teachers feel that they have little control over how their schools are operated or over what textbooks and teaching methods are used in their classrooms. In addition, teachers feel that they are overloaded with other responsibilities at their schools besides teaching.

Various plans have been suggested for improving teacher performance. These plans include *in-service training, master-teacher programs, merit-pay programs,* and *national certification.* In-service training helps working teachers improve their performance. In master-teacher programs, successful, experienced teachers work closely with beginning teachers to provide support and advice. Merit-pay programs reward teachers with additional pay if their students regularly achieve at high levels. National certification is a movement to improve teaching by creating high standards of training and performance for teachers throughout the United States. The nonprofit National Board for Professional Teaching Standards was founded in 1987 to develop these standards and grant national certification.

To improve teacher quality, many states have introduced basic tests that teachers must pass before they can receive their teaching credential. In some states, current teachers could not pass these tests, causing major concerns about the quality of the teaching profession.

In the mid-1980's, some school districts began experiencing teacher shortages. Many districts relaxed certification requirements so that people who had worked in other fields could become teachers. In addition, many school systems raised salaries to make teaching a more attractive career choice. In the 1990's, shortages of science and mathematics teachers led some schools to pay higher salaries to teachers of these subjects.

Education for whom? During the mid-1900's, several groups began to win educational opportunities previously denied to them. They included women, people with disabilities, and blacks and other minority groups.

School desegregation. In 1954, the Supreme Court of the United States ruled in *Brown v. Board of Education of Topeka* that racially segregated public schools were unconstitutional. The court based its decision on the constitutional guarantee of equal protection under the law. Seventeen states and some school districts in other states had school segregation laws in 1954. By the early 1960's, a few states affected by the Supreme Court ruling had integrated all their school districts. By 1970, every U.S. state had at least some integrated schools, though integration remained far from complete.

The Supreme Court renewed its support of integration in 1971, when it ruled in *Swann v. Charlotte-Mecklenburg Board of Education* that students could be bused to different schools to achieve desegregation. It was not until 1999 that the Charlotte-Mecklenburg district regained control of its desegregation efforts, without the need for judicial review. Despite public opposition, many school districts adopted extensive busing programs to promote integration. But by the late 1980's, studies showed that most minority students still attended schools with predominantly minority enrollment. This failure to achieve racial balance led to growing opposition to busing among both white and minority families.

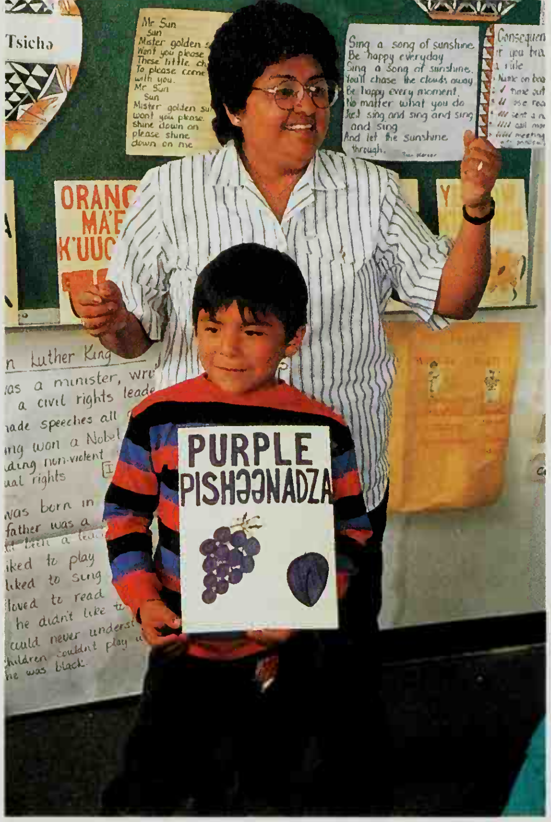
In the 1990's, several Supreme Court decisions limited schools' obligation to use busing and other measures to encourage desegregation. One ruling was the 1991 case *Board of Education of Oklahoma City v. Dowell.* This ruling found that even schools that remained segregated could end desegregation programs as long as districts had eliminated deliberate segregation.

Bilingual education. Many students from Hispanic American, Asian American, and other minority groups have had fewer opportunities in school because their native language is not English. The federal government began to provide funds for *bilingual education* (teaching in two languages) in public schools in 1968. In 1974, the Supreme Court ruled in *Lau v. Nichols* that schools must provide special programs for students who do not speak English. See **Bilingual education**.

Bilingual education has become increasingly important in areas of the United States that have growing Asian and Hispanic populations. Experts predict that the number of Asian and Hispanic students in U.S. schools will continue to grow rapidly in the 2000's. By the early 2000's, Hispanic Americans are expected to form the largest minority group in the United States.

Multicultural education provides opportunities for students to learn about and appreciate the tremendous cultural diversity that characterizes the United States. In addition, it helps students develop favorable images of themselves and of people from other cultures.

In the early 1900's, the United States and its schools functioned as a "melting pot." That is, schools brought together people from different cultures and taught them to think of themselves only as Americans. In the 1960's, though, the civil rights movement drew attention to conflicts between groups in U.S. schools and communities. One response to this problem was the *human relations curriculum.* It stressed relationships among groups and helping people from all backgrounds view themselves favorably. By the early 1970's, the program had expanded to examine such issues as recognizing the impor-



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Bilingual education teaches in two languages, a new language and one that a student already speaks. This Native American teacher and student are working on the names of colors.

tance of both personal heritage and community. It also challenged teachers to deal with cultural diversity beyond the ethnic makeup of a local school or community.

Education for children with disabilities. During the 1970's and 1980's, public education services were extended to many children with physical or learning disabilities. In 1975, Congress passed the Education for All Handicapped Children Act. This act ordered the states to provide a free education for any disabled child of school age. In 1986, the act was extended to include preschool-age disabled children. Most students with physical or learning disabilities are *mainstreamed* (taught in regular classrooms). They may spend part of each day working with specially trained teachers.

Nonsexist education. Girls and women have also won many new educational opportunities. Title IX of the Education Amendments Act of 1972 prohibited discrimination on the basis of sex by universities and other schools receiving federal funds. In 1975, the government issued detailed regulations outlawing such discrimination in admissions, athletics, course offerings, hiring, and other school activities. As a result, home economics, shop, and other classes became coeducational. Schools also began to admit girls to boys' sports teams or to provide separate girls' teams. In the 1980's and 1990's, the number of women enrolled in colleges and universities continued to grow. More women also served on their faculties.

How should schools be run? Many proposals for improving U.S. education involve sweeping changes in how schools are organized and operated. Such changes are often called *school restructuring* or *school reform.* Restructuring generally tries to create a more flexible school structure that encourages new ideas and creativity. It also transfers decision-making authority from central-office administrators to principals and teachers.

Restructuring is difficult to put into practice. Many school systems, however, have adopted a procedure called *school-site management* or *school-based management.* In this procedure, a team that typically consists of community leaders, parents, and teachers may help set school policies, select textbooks, manage the school budget, and participate in hiring teachers or even a principal. Thus, decision making occurs at the local school level, close to the students who are served by the school. The Chicago public schools began such a program of school reform in 1989. Under this program, an elected council of parents, teachers, and community representatives has a major role in running each school.

How should education be financed? About three-fourths of the money spent on U.S. education goes to support elementary and secondary schools. Federal, state, and local funds are used. In most states, school districts raise money largely through property taxes.

The property tax has increasingly come under attack as an unfair method of financing public education. Poor school districts raise far less money from property taxes than rich districts do because the total property value in poor districts is much lower. As a result, rich districts can provide better schools and educational programs than poor districts, often with lower property tax rates.

In 1973, the Supreme Court of the United States ruled in the case of *San Antonio Independent School District v. Rodriguez* that using property taxes to finance public schools did not violate the U.S. Constitution, despite large differences in taxes and spending among Texas school districts. The court acknowledged, however, the need for reform in school financing and left the way open for action by state legislatures. In fact, many state constitutions require schools to provide equal educational opportunities, or call for "thorough" education. These requirements have formed the basis for challenges to property tax-based school funding programs in many states. In other states, the threat of legal action has encouraged state legislatures to act.

There has also been a growing effort to reduce property taxes across the United States. Beginning with Proposition 13 in California in 1978, states—or their taxpayers—have sought ways to reduce the dependence on local property taxes. This effort has given states a much larger role in deciding how schools are funded. In many cases, states are working to provide equal funding to school districts and to reduce large differences in the property taxes paid by individuals in different districts. In 1994, Michigan became the first state to sharply reduce the use of property taxes in financing its public schools.

At the beginning of the 2000's, many concerns about financing education involved the amount of money spent per student. One concern focused on whether the amount spent is enough to meet the educational needs of each child. Many individuals want to see states spend more money on education. The problem with determining adequate spending levels has been in determining what constitutes an adequate education and then estimating what such an education should cost.

Many people also wonder how much student performance will improve if more money is spent on education. Unfortunately, the research on this issue is not clear. Those who argue that more money will lead to better student performance do not know how much money it takes to make significant improvements. Others question whether there is a direct relationship between learning and the amount of money spent. These issues are made even more difficult by the growing recognition that children from diverse backgrounds may need different educational programs to succeed.

Lawrence O. Picus

Related articles in *World Book.* See the *Education* section of articles on various countries, and the *People* section of the articles on states and provinces. See also:

Outline

V. Learning and teaching
  A. How people learn
  B. How teachers guide learning
VI. History
VII. Current issues in U.S. education

Questions

How are U.S. public schools supported?
What are the three areas into which educational objectives are divided?
How did people in prehistoric times provide education for their children?
What are private schools? How are they supported in the United States?
What unit of government in the United States has general authority over public education?
What is the aim of general education? What is the aim of vocational education?
What are segregated schools? Why did the United States Supreme Court declare these schools unconstitutional?
Which state passed the first compulsory school-attendance law? When?
Why are many children in developing countries unable to receive even an elementary education?
Where did the first modern universities develop? When did they develop?

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Education, Department of, is an executive department of the United States government that works to improve American education. It also promotes equal educational opportunities for all U.S. citizens.

The secretary of education, a member of the president's Cabinet, heads the department. The president appoints the secretary with the approval of the United States Senate.

Functions. The responsibilities of the Department of Education fall into six main categories: (1) providing leadership in addressing critical issues in American education; (2) assisting in the collection of ideas for the improvement of education; (3) helping students pay for their education beyond high school; (4) helping communities and schools meet the needs of their students; (5) preparing students for employment; and (6) working to ensure equal educational opportunities for all Americans. The department also administers programs to improve the skills of students who are not fluent in English. In addition, the department collects data—and oversees research—on the nation's schools and informs educators and the general public of its findings.

The seal of the United States Department of Education

The department is concerned with schools at all levels, including preschools, elementary schools, high schools, and colleges and universities. It also focuses on technical training, adult education, and education and training for disabled children and adults.

History. In 1867, Congress set up a non-Cabinet federal agency called the Department of Education. Congress later renamed the agency the Bureau of Education and made it part of the Department of the Interior. Still later, it renamed the bureau the Office of Education and moved it to the Federal Security Agency. In 1953, the Office of Education became part of the newly created Department of Health, Education, and Welfare (HEW). In 1972, Congress set up the Education Division within HEW. The Education Division included the Office of Education, the National Institute of Education, the Fund for the Improvement of Post-Secondary Education, and the National Center for Education Statistics.

Mid Hunt

Headquarters of the United States Department of Education, *shown here,* are in Washington, D.C. The Department of Education promotes educational opportunities for all U.S. citizens.

Secretaries of education

Name	Took office	Under President
*Shirley M. Hufstedler	1979	Carter
Terrel H. Bell	1981	Reagan
William J. Bennett	1985	Reagan
*Lauro F. Cavazos	1988	Reagan, G. H. W. Bush
Lamar Alexander	1991	G. H. W. Bush
Richard W. Riley	1993	Clinton
Roderick R. Paige	2001	G. W. Bush

*Has a separate biography in World Book.

Congress created the Department of Education in 1979. The department began operating in 1980. It absorbed the Education Division of HEW, and HEW became the Department of Health and Human Services. The Department of Education also took over educational programs from other government agencies. For example, it took over the law enforcement education programs of the Department of Justice and the migrant worker education programs of the Department of Labor.

Critically reviewed by the Department of Education

See also **FFA; Flag** (picture: Flags of the United States government); **National Assessment of Educational Progress; National Defense Education Act.**

Education, Early childhood. See Early childhood education.

Education, Vocational. See Vocational education.

Education Amendments Act of 1972. See Education (Providing financial aid).

Education Association, National. See National Education Association of the United States.

Education Week, American, acquaints the public with the work of education, and with its problems, achievements, and needs. It is sponsored by The American Legion, the National Education Association, the National Congress of Parents and Teachers, and the United States Department of Education. Education Week, first observed in 1921, is now held each year in the fall. Other countries have adopted the custom of observing an education week under the leadership of the World Federation of Education Associations.

A typical American Education Week program opens with proclamations from state governors and mayors. These proclamations stress the importance of education. The rest of the week includes such activities as open house programs, special television programs, and exhibits in businesses, schools, and libraries.

Each year, the sponsoring organizations select a theme for American Education Week. Themes have included *Better Education—Your Job; America Has a Good Thing Going—Its Schools;* and *Invest in Learning.*

Critically reviewed by the National Education Association of the United States

Educational foundations and endowments. See Foundations.

Educational guidance. See Guidance (Educational guidance).

Educational measurements. See Testing.

Educational psychology is a field of psychology in which psychological knowledge and methods are used to study the processes of teaching and learning. Educational psychology combines psychology and education by applying the scientific study of human behavior to educational goals. Such study provides the information that teachers need in order to help students learn.

What educational psychologists study. Educational psychologists conduct many kinds of research. They study how people change while growing from infancy to old age. Psychologists thus discover what kinds of behavior are typical of students at different ages. Educators use such information to develop effective teaching methods for various age groups.

Educational psychologists analyze individual differences among students and determine the effect these differences have on learning. Attitudes, intelligence, social adjustment, and other characteristics vary greatly among students and affect how well students learn. By understanding these differences, teachers may develop better instructional methods.

Educational psychologists also study the principles of learning. Such research provides teachers with information about how students learn and what stimulates them to learn. Educators use this information to design curriculums. Educational psychologists also develop tests and other methods of measuring what students have learned and how much they are able to learn.

Careers in educational psychology. Many educational psychologists are professors of education at colleges and universities. They instruct both future and experienced teachers in the psychological principles that apply to classroom learning. Some educational psychologists work in research laboratories, where they may develop new testing techniques or methods of instruction. Others work in elementary and high schools, where they help students, parents, and teachers solve problems related to school and learning.

Most educational psychologists employed by universities and research laboratories have a Ph.D. degree. Educational psychologists who work in public schools must have an M.A. or M.Ed. degree. Many of these psychologists also have a Ph.D. or Ed.D. The major professional organizations for educational psychologists in the United States are the American Psychological Association and the American Educational Research Association.

Janice T. Gibson

Related articles in *World Book* include:

Developmental psychology
Education (Learning and teaching)
Learning
Psychology
Teaching
Testing

Edward (1330-1376), known as the Black Prince, is one of the most famous English warriors in history. He was the oldest son of King Edward III and the father of King Richard II.

According to later tradition, he wore black armor at the Battle of Crécy in France in 1346. Although he was only 16 years old, Edward commanded a wing of his father's army in this first great battle of the Hundred Years' War (1337-1453). In 1356 at Poitiers, France, Edward defeated a French army and captured the French king.

John Gillingham

Detail of bronze statue from the tomb of Edward by an unknown artist; by the kind permission of the Dean and Chapter of Canterbury, Canterbury Cathedral, Canterbury

Edward, the Black Prince

Edward I (1239-1307) became king of England in 1272. As king, he conquered Wales and tried to gain control of Scotland. Edward belonged to the Plantagenet family of English rulers.

Detail from a manuscript by an unknown artist, The British Library, London

Edward I

Edward I was born in Westminster (now part of London). He succeeded his father, Henry III, as king. Edward fought two wars against the Welsh, one in 1277 and another in 1282 and 1283. He conquered Wales in the second war. In 1301, Edward gave the title Prince of Wales to his son, who later became Edward II. Since then, it has become customary for English monarchs to give the title to their oldest son.

In 1292, Edward chose John de Balliol as ruler of Scotland from among several men who claimed the Scottish throne. Edward demanded that Balliol pay homage to him. But this demand humiliated the Scottish people, causing them to revolt. In 1296, Balliol joined the rebel forces, but Edward forced him to surrender. Edward then took to England the Stone of Scone, the stone upon which Scottish kings had been given royal power for hundreds of years. He placed the stone in Westminster Abbey, where English monarchs were crowned.

But the Scots continued to fight England. They were led first by William Wallace and then by Robert Bruce. Bruce was crowned king of Scotland in 1306. Edward died while on his way to subdue the new king.

Edward's Scottish policy resulted in hostile relations between the English and the Scots for the next 250 years. It also led to an alliance between Scotland and France. As a result, England had to fight both countries at the same time. Edward's need for money to supply his army and government led him to call Parliaments more often than had any previous king. These Parliaments consisted of representatives of the nobility, the church, and common people. In return for grants of money from Parliament, Edward agreed that taxes could be levied only with Parliament's consent. He also sponsored laws on more topics than any previous king.

Edward I was not the first English king named Edward. People in England give numbers to their kings and queens with the same name only if the monarchs ruled after the Norman Conquest of 1066. There were three Anglo-Saxon kings named Edward who ruled England before 1066: Edward the Elder (870?-924), Edward the Martyr (963?-978?), and Edward the Confessor (1002?-1066). See **Edward the Confessor.** John Gillingham

See also **Bruce, Robert; Model Parliament; Wallace, Sir William.**

Edward II (1284-1327) was one of the most unsuccessful kings in English history. He was a poor general and was disliked by nearly all his barons and even by his wife, Queen Isabella.

Edward, a member of the Plantagenet royal family, was born in Caernarfon, Wales. He was the first heir to the English throne to receive the title Prince of Wales. He succeeded his father, Edward I, in 1307. The young king's reign was troubled by many political trials and executions. In 1314, he lost an important battle to the Scottish leader Robert Bruce at Bannockburn, Scotland.

In 1325, Queen Isabella visited France. From there, she and her lover, Roger Mortimer, organized an invasion of England. They and their supporters forced Edward to give up the throne to his son Edward III in 1327. Edward II was murdered that year. John Gillingham

See also **Bannockburn, Battle of; Prince of Wales.**

Edward III (1312-1377) became king of England in 1327. He succeeded his father, Edward II, and belonged to the Plantagenet family of English rulers. During the 1330's, Edward invaded Scotland. He won victories there, but he could not crush the Scottish spirit of independence.

Edward's forces won the Battle of Crécy in what is now the Normandy region of France. This conflict was the first major battle between France and England in the Hundred Years' War (1337-1453). Edward claimed to be the rightful king of France, and he conquered much of that country. He paid for the war by introducing an efficient system of taxing imports. In the last few years of his reign, Edward failed to provide vigorous leadership. The French recovered some of their land, and Edward's popularity declined. Even so, he was long remembered as an ideal king and a fine soldier. Edward was born in Windsor, near London. John Gillingham

See also **Edward** (the Black Prince); **Hundred Years' War; Salic Law.**

Edward IV (1442-1483) became king of England in 1461. He was the son of Richard, Duke of York, and was the first king of England from the House of York. Before Edward's reign, the Houses of York and Lancaster—two branches of the royal Plantagenet family—had begun fighting each other in the Wars of the Roses (see **Wars of the Roses**).

As leader of the Yorkists, Edward was proclaimed king in 1461 by supporters in London and then won a major victory at Towton against the forces of Henry VI of the House of Lancaster. But in 1470, the powerful Earl of Warwick shifted his support to the House of Lancaster. Edward then fled to Holland (see **Warwick, Earl of**). The next year, Edward returned with an army and regained the throne. He then ruled England until his death in 1483. As king, Edward strengthened the royal power and paved the way for the absolute monarchy of the Tudors. Edward IV was born in Rouen, France.

Detail of an oil portrait by an unknown artist; National Portrait Gallery, London.

Edward IV

Ralph A. Griffiths

Edward V (1470-1483?) succeeded his father, Edward IV, as king of England in April 1483 at the age of 12. But before he was crowned, his father's brother, Richard, Duke of Gloucester, imprisoned Edward and Edward's younger brother, also named Richard, in the Tower of London. In June, Gloucester took the throne as Richard III. Edward and his brother were probably murdered soon afterward on an order from Richard III. However,

there is no proof of murder, and no one knows for certain what happened to the boys. The remains of two children were discovered in the Tower of London in 1674, and some people believe that they may have been those of Edward and his brother.

Edward was born at Westminster (now part of London). He lived most of his short life in the borderlands between England and Wales.

Detail of an engraving by George Vertue based on a drawing in a manuscript book in the library at Lambeth, England. From *History of England* by Rapin de Thoyras

Edward V

Ralph A. Griffiths

Edward VI (1537-1553) was king of England and Ireland from 1547 until his death. He was the son of King Henry VIII, whom he succeeded. Edward's mother was Jane Seymour, Henry's third wife. Edward belonged to the English ruling family known as the House of Tudor.

Edward was only 9 years old when he became king, so his uncle Edward Seymour, who soon became the Duke of Somerset, governed for him. In 1549, the Earl of Warwick, later called the Duke of Northumberland, took Somerset's place. Edward, Somerset, and Northumberland all wished England to remain Protestant.

Tempera and oil painting on wood by Hans Holbein the Younger; the Metropolitan Museum of Art, New York City. The Jules S. Bache Collection, 1949

Edward VI

When Edward was 15 years old, he became fatally ill with tuberculosis. Before Edward died, he named his Protestant cousin Lady Jane Grey, who was also Northumberland's daughter-in-law, as his successor. Edward's half sister Mary had been next in line for the throne, but she was a devout Roman Catholic. Lady Jane reigned for only nine days before she was dethroned in favor of Mary. Edward VI was born in what is now part of London.

Richard L. Greaves

Edward VII (1841-1910) became king of the United Kingdom of Great Britain and Ireland in 1901. He was the first son of Queen Victoria and Prince Albert and belonged to the royal family of Saxe-Coburg-Gotha.

Edward was born in London and became Prince of Wales when he was an infant. His given name was Albert Edward. He studied at Edinburgh, Oxford, and Cambridge universities. In 1863, he married Princess Alexandra, whose father later became King Christian IX of Denmark.

Visual Educ. Serv.

Edward VII

During Queen Victoria's widowhood, Edward represented her at public gatherings (see **Victoria**). He was a patron of the arts and sciences and helped found the Royal College of Music. He was also one of England's leading sportsmen. Horses from his stables won the English Derby three times.

Edward was greatly interested in foreign affairs. On a visit to India in 1875 and 1876, he improved relations between Britain and the princes of India. His official visit to France in 1903 helped make renewed friendship between Britain and France a lasting reality. He became the first reigning British monarch to visit Russia, and his presence there in 1908 strengthened the Anglo-Russian agreement of 1907. His son, George Frederick, succeeded him in 1910 as King George V. James J. Sack

Edward VIII (1894-1972) became king of Britain on Jan. 20, 1936, and gave up the throne on December 11 that same year. He was the oldest son of King George V and Queen Mary of the English ruling family known as the House of Windsor. Edward succeeded his father as king.

Edward was born in London. He was made Prince of Wales in 1911 at Caernarfon Castle, Wales. He was the first Prince of Wales to deliver his address in Welsh. Edward was educated at the Royal Naval College and at Oxford University. He served in World War I (1914-1918) as aide-de-camp to Sir John French, who during part of the war was commander of the British Expeditionary Force in France.

Foulsham & Bansfield, United Press Int.

Edward VIII

The prince became a great traveler, and was often called *the empire's salesman.* After World War I, Edward visited Canada, the United States, South America, Africa, India, Australia, and New Zealand, promoting world peace, British trade, and the unity of the British Empire. His democratic spirit, charm, and diplomacy made him popular. In Britain, he took an interest in the living conditions of the underprivileged and working classes.

Edward fell in love with Wallis Warfield Simpson, an American divorcée. Because his government and many of his subjects were opposed to accepting her as queen, Edward abdicated his throne. He then left England in self-imposed exile. His brother, George VI, who succeeded him, gave him the title Duke of Windsor. Edward married Simpson in June 1937. In 1939, he visited England for the first time since his abdication. He volunteered for a military position during World War II (1939-1945) and was made a liaison officer. In 1940, George VI made him governor of the Bahamas, then a British colony. He served there until 1945. After the war, Edward lived mostly in France. Keith Robbins

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Edward, Lake. See Lake Edward.

Edward the Confessor (1002?-1066), an Anglo-Saxon king descended from Alfred the Great, was crowned in 1042. As king, Edward lacked influence among England's Anglo-Saxon nobles because he had lived in the Normandy region of northwestern France before becoming king. Edward's Anglo-Saxon father-in-law, Godwin, Earl of Wessex, tried to dominate Edward's reign. Edward resisted Godwin's efforts by relying on Norman advisers and administrators. Godwin died in 1053.


Statue in a niche in the grille surrounding the tomb of Henry VII, Westminster Abby, London

Edward the Confessor

Edward was a pious man. In the mid-1000's, he built a church that became Westminster Abbey. In 1161, Pope Alexander III *canonized* him (declared him a saint) and gave him the title of Confessor.

Edward was childless, and a dispute arose over who should succeed him. His cousin William, Duke of Normandy, claimed Edward had promised him the throne. But when Edward died in 1066, the English nobles chose Harold, Godwin's son, as king. Harold took the throne as Harold II. William then invaded England, defeated Harold, and was crowned king (see **William I, the Conqueror**). Joel T. Rosenthal

See also **Westminster Abbey**.

Edwards, Jonathan (1703-1758), was a famous minister of Puritan New England. As a philosopher, preacher, revivalist, and theologian, he became the leading intellectual figure in colonial America.

Edwards was born in East Windsor, Connecticut. Many of his forefathers had been Congregational pastors. He entered Yale University at age 13 and graduated at 17. In 1726, he became assistant pastor of a congregation in Northampton, Massachusetts. The chief pastor was his grandfather, Solomon Stoddard, a famous Congregational clergyman. After Stoddard died in 1729, Edwards became chief pastor.


The Granger Collection

Jonathan Edwards

During the 1730's and 1740's, Edwards's sermons contributed to a series of religious revival movements that spread through New England. These movements became known as the *Great Awakening*. They led to a new, more spiritual understanding of the church. At the same time, Edwards defended many traditional church doctrines. He was attacked and praised by both radicals and conservatives. His aim was to reconcile traditional Calvinist teachings with the notions of religious experience in the 1700's. See **Great Awakening; Calvin, John**.

During the Great Awakening, Edwards wrote a number of works on the psychology of religion. Edwards based these writings on his observations of how people behaved during intense religious experiences.

In the late 1740's, Edwards tried to exclude from the sacrament of the Lord's Supper any parishioner who had not had a distinct conversion experience. Some members of his congregation opposed this change, and Edwards was dismissed in 1750. From 1751 to 1757, Edwards was a missionary to an Indian settlement in Stockbridge, Massachusetts. There, he wrote his major philosophical work, *Freedom of Will* (1754). In it, he defended the Christian doctrine of predestination (see **Predestination**). He argued that people's choices in life depended on their character, "inclined" either by God or by sinful human nature. Mark A. Noll

Edwards Air Force Base, California, is the site of the United States Air Force Flight Test Center. It also houses the Ames-Dryden Flight Research Center of the National Aeronautics and Space Administration (NASA). The base covers about 301,000 acres (121,800 hectares) in the Mojave Desert, northeast of Los Angeles. Test pilots fly experimental aircraft nearby. Edwards also serves as a landing site for U.S. space shuttles.

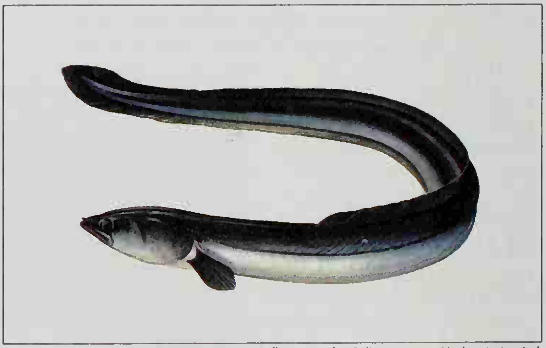
The base was established as a bombing and gunnery range in 1933. It became Muroc Army Air Field in 1940. In 1949, the base was renamed for Captain Glen Walter Edwards, a test pilot killed in an aircraft crash nearby. Wayne Thompson

EEG. See **Electroencephalograph**.

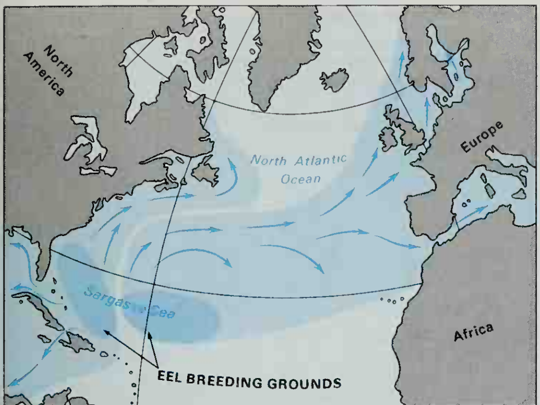
Eel is a long, slimy fish that looks like a snake. There are about 600 kinds of eels. Most live in the ocean. Such saltwater eels include morays, congers, and snipe eels. Scientists know little about these eels. The most studied eels belong to a group often referred to as "common eels." These eels can live in both salt water and fresh water. This article discusses common eels.

Common eels include the *American eel* and the *European eel*. American eels live along the Atlantic coast of North America. European eels are found along the Atlantic coast of Europe and in the Mediterranean Sea.

Life cycle. Both American eels and European eels begin life in the Sargasso Sea, an area of the Atlantic Ocean northeast of the West Indies. The female eel lays eggs there in spring. Each egg hatches into a tiny, narrow *larva,* the next stage in eel development. The larva, called a *leptocephalus,* resembles a clear willow leaf. As ocean currents carry it northward, it undergoes a *meta-*


WORLD BOOK illustration by Colin Newman, Linden Artists Ltd.

The eel is a long, thin fish that resembles a snake. The species shown is a European eel.



WORLD BOOK map

European and North American eels leave their freshwater streams and breed in the Sargasso Sea. They then die. The young eels later migrate to fresh water, as shown by the arrows.

morphosis (change in body form) and develops into a transparent, miniature eel, called a *glass eel.*

By the time this miniature eel reaches the coast of North America or Europe, it has developed some coloration and is known as an *elver.* Scientists believe that male elvers stay in salt water along the coast. Most female elvers swim into rivers and other bodies of fresh water. Elvers are strong swimmers, and the female may climb waterfalls or dams to reach inland waters.

The elver gradually increases in size and turns a dull, yellowish-green. It is then called a *yellow eel.* During this stage, which usually lasts 7 to 10 years, the eel reaches its full size. Most females grow 3 to 4 feet (91 to 122 centimeters) long and most males about 1 $\frac{1}{2}$ feet (46 centimeters) long. Eventually, the eel undergoes a second metamorphosis and becomes an adult. The skin color on its sides changes to silver, its eyes get larger, and it becomes sexually mature and able to breed. In its adult stage, the eel is called a *silver eel.*

Migration. Each fall, large numbers of silver eels group together and begin to migrate back to the Sargasso Sea for breeding. During this migration, the eels may travel across any land that blocks their path. Scientists do not know how the eels find their breeding places. Some researchers believe that eels use their sense of smell to find their way back. Others believe eels rely on ocean currents for direction. Studies have shown that eels can detect weak electric currents generated by movements of water. These small electric currents may serve as navigational guideposts for the eels.

Eel fishing. Common eels are considered delicacies in Europe and Asia. European and Asian fishing crews harvest great numbers of eels each year. Eels are caught in large nets or in specially built cages. In the United States, eel fishing is a minor industry. John J. Poluhowich

Scientific classification. Eels belong to the order Anguilliformes. Common eels are members of the family Anguillidae. The scientific name for the American eel is *Anguilla rostrata.* The European eel is *A. anguilla.*

See also **Electric eel**; **Fish** (pictures).

Eelgrass is the name of two species of underwater plants. One species grows in salt water and the other in fresh water.

Marine eelgrass grows in muddy, shallow bays along the Atlantic and Pacific coasts of North America. It roots on the ocean bottom and bears slender, floating stems. Its tapelike leaves may be 6 feet (1.8 meters) long. Wild ducks and geese eat the plants. About 1930, the eelgrass along the Atlantic coast began to die. However, the plants have begun to grow again in some places.

Freshwater eelgrass is also known as *tape grass* and *wild celery.* It grows in the mud of shallow ponds, sending ribbonlike leaves from the root. James D. Mauseth

Scientific classification. Marine eelgrass belongs to the family Zosteraceae. Its scientific name is *Zostera marina.* Freshwater eelgrass belongs to the frogbit family, Hydrocharitaceae. It is *Vallisneria americana.*

Eelworm is a tiny, threadlike worm that lives as a parasite in plants. Eelworms are also called *plant nemas.* They may cause losses of millions of dollars a year to farmers. Certain eelworms attack plant leaves, stems, or roots and produce hard swellings called *galls.* Other destructive eelworms can puncture plant tissue and suck cell sap out through their hollow, spearlike *stylets.* The eggs and *larvae* (young) of many eelworms can withstand cold and dryness for relatively long periods. Warmth and moisture make them active again. Female eelworms can become so swollen with eggs that they look like tiny lemons. They soon die and the body wall forms a tough *cyst* (sac). The eggs are released when the cyst breaks. David F. Oetinger

Scientific classification. Eelworms belong to the roundworm phylum Nematoda.

Efficiency, in engineering and physics, is the ratio of the work we get *out* of a machine to the amount of energy put *into* the machine. The difference between the energy put in and the work delivered often appears in the form of heat due to friction. For example, most of the electrical energy going into an electric motor is put out as mechanical energy by turning a shaft that does useful work, such as pumping water or drilling. But part of the energy given to the motor is wasted as heat in the bearings and wires. Scientists express efficiency in percentage. If a motor returns three-fourths of the energy put into it, the motor has an efficiency of 75 percent. Human beings have an efficiency of about 24 percent in converting the energy in the food we eat into mechanical energy, such as running or walking. An electrical transformer can be over 98 percent efficient. See also **Energy**; **Machine.** James D. Chalupnik

Effigy Mounds National Monument, *EHF uh jee,* is located in northeastern Iowa, 3 miles (5 kilometers) north of Marquette. It contains prehistoric mounds. Some of the mounds are 300 feet (91 meters) long and were built in the form of animals. The monument was established in 1949. For the monument's area, see **National Park System** (table: National monuments).

Critically reviewed by the National Park Service

Eft. See **Newt.**

EFTA. See **European Free Trade Association.**

Egbert (?-839) was king of Wessex in England from 802 until his death. Egbert may have tried to claim the throne after the death of the Wessex king in 786. But the new king and the king of Mercia drove him into exile. Egbert lived for several years in the kingdom of the Franks, at the court of Charlemagne. Egbert returned in 802 and became king of Wessex. He fought for control of the

other Anglo-Saxon kingdoms. Egbert eventually gained the submission of Kent, Sussex, Surrey, Essex, Mercia, East Anglia, and Northumbria, as well as the Celts in Cornwall. Egbert's reign laid the basis for the unification of England under his heirs, beginning with his grandson Alfred the Great. See also **Anglo-Saxons; England** (The Anglo-Saxon period). Mary Frances Smith

Egg. Most people think of an egg only as a kind of food produced by chickens. But all birds lay eggs, although few besides chicken eggs are used as human food. Nearly all animals produce eggs. But only certain animals, such as birds, force the eggs out of the body. The main purpose of all eggs is to produce young. In all ranks of animal life above the very lowest, young animals can develop only from eggs. Except in special cases, such as in bees, the young develop only after the egg is *fertilized*—unites with a male sex cell (see **Fertilization**).

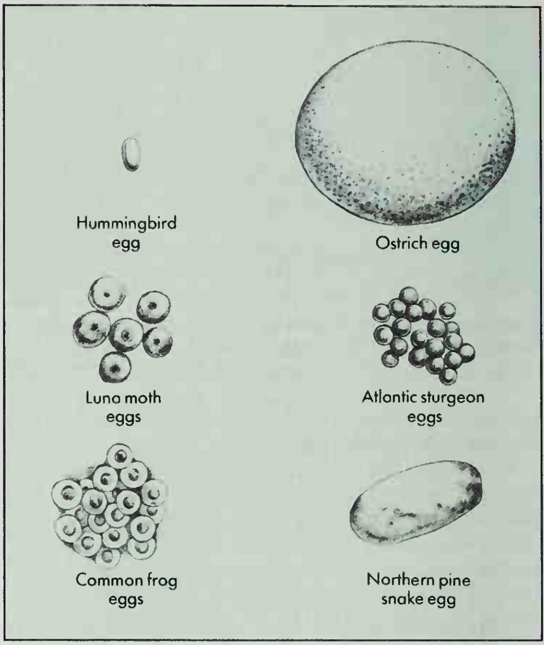
In nearly all mammals, the fertilized egg is very small and stays inside the mother's body. As a result, the young mammal develops from the egg within its mother's body. In due time, a young animal is born.

Female birds, and most insects, fishes, and reptiles force the fully formed egg out of the body. A bird's egg is much larger than a mammal's egg because it contains food for the young bird to use while it develops outside of the mother's body. When the egg is kept under proper conditions for a certain length of time, it develops into an animal resembling its parents.

Some kinds of eggs

All higher animals produce eggs. This illustration shows eggs laid by birds, an insect, a fish, an amphibian, and a reptile. They are not shown in their actual size relationships.

WORLD BOOK illustration by Jean Helmer



Kinds of eggs

Birds' eggs vary greatly in size, shape, and in color (see **Bird** [picture: Birds' eggs]). Usually, the larger birds lay the larger eggs. For instance, the ostrich lays a very much larger egg than the hummingbird. There are exceptions, however. The Indian Runner duck, for example, is smaller than the Plymouth Rock hen, but lays a larger egg. The number of eggs that wild birds lay varies greatly. The hornbill lays 1 egg a year. Gulls lay 4 eggs a year. The gray lag goose lays 5 or 6 eggs, and the mallard duck 6 to 15. The partridge may lay 12 to 20 eggs a year. Hens and some ducks can lay up to 350 eggs or more in a single year. Most wild birds lay their eggs in carefully built nests. A few lay their eggs on ledges of rocks, and others bury their eggs in the sand. Still others make a pile of decaying plants and bury their eggs in it.

The eggs of wild birds have a wide range of colors, from the white of the flicker's egg to an almost solid black of some ducks. There is a great variety of color patterns and markings of blues and browns among the eggs laid by other wild birds. It is often possible to identify a wild bird by its eggs. Leghorns and other hens of the Mediterranean class lay white-shelled eggs. Most other chickens lay brown-shelled eggs, but the Araucana hens of South America lay blue-shelled eggs. Most wild birds' eggs are similar in shape to the tame hen's egg. Some are different. The plover's egg is pear-shaped, and the owl's is round. The sandgrouse's egg is shaped like a cylinder.

Other kinds of eggs. There are many kinds of eggs. The earthworm lays eggs enclosed in capsules filled with a milky nourishing fluid. The female water-flea produces summer eggs, which she carries in a pouch on her back, and winter eggs, which are enclosed in capsules. The eggs of moths, butterflies, and other insects are very small. They have many different forms and colors. These insects usually lay their eggs in clusters on the ground, on leaves or the stalks of plants, or in water.

The oyster may produce as many as 500 million eggs a year. Oyster eggs and young oysters are eaten by many forms of water life, and relatively few survive. Fishes also lay large numbers of eggs, so that enough of the eggs survive to be fertilized and produce young fishes. The sturgeon lays about 7 million eggs a year. Most other fishes lay fewer eggs than this. Some fish eggs are heavy and sink to the bottom of the stream, lake, or ocean. Other kinds of fish eggs are light and transparent, and float in masses on the water.

The common toad produces as many as 6,000 eggs at a time in two long strings of jelly. The common frog produces a large, jellylike mass of eggs. Egg-laying snakes lay about 20 to 30 eggs a year.

The parts of an egg

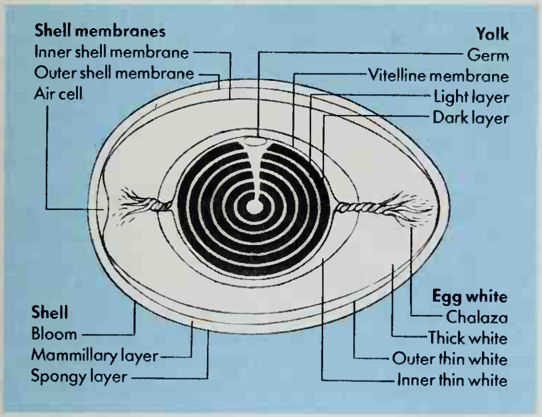
The most important part of an egg is the *germ* (nucleus). This part develops into the new animal. The other elements or parts of an egg provide food and protection for the young animal.

A bird's egg has five principal parts: the shell, the shell membranes, the white, the yolk, and the germ.

The shell is composed of two main layers—an inner *mammillary layer* and an outer *spongy layer.* These layers contain pores so water and gases can pass through the shell. A thin film called *bloom* covers the outside of a fresh egg. Bloom tends to seal the egg's pores, reducing the loss of water and gases. Eggs laid by different

Parts of a chicken egg

WORLD BOOK illustration by Zorica Dabich



hens sometimes vary greatly in thickness of shell and the size and number of pores.

Shell membranes. Located just inside the shell are two very thin white *membranes* (skins). These are the outer-shell membrane and the inner-shell membrane. They lie close to each other, except at the large end of the egg, where they are separated to form the air cell. Water and gas can pass through these membranes. When the egg is laid, it contains no air cell until it cools and contraction forms a space between the two membranes. The longer the egg is kept, especially in a dry, warm place, the larger the air cell becomes. This is because water and gas have escaped from the egg, leaving space. The shell membranes surround the *albumen* (white) portion of the egg.

The white of an egg is made up of four different parts. On the outside is a layer of thin white, then a layer of thick white, and then another layer of inner thin white. Inside this innermost layer of thin white, there is a layer of thick white surrounding the yolk. This layer of thick white is twisted in a ropelike structure at each end of the yolk and forms what is known as a *chalaza.* The chalazas are attached to the thick albumen. Chalazas help anchor the yolk, but allow it to turn easily. They help save the yolk from damage.

The yolk is contained in a yolk sac called a *vitelline membrane.* When a fresh-laid egg is resting on its side or end, the yolk stays slightly above the center of the egg because the yolk is lighter than the white. The *germ,* or *germ-spot,* is an area about the size of a pinhead on the upper surface of the yolk. It can be identified easily, because it is lighter in color than the rest of the yolk, and is sometimes slightly raised. The germ in a fertile egg that is kept under suitable conditions develops into the embryo. A two-yolk egg or double-yolk egg may be fertile, but it seldom hatches. Eggs for market use should be infertile or should be kept at relatively low temperatures to prevent embryonic development. Eggs in which the embryo begins to develop are not suitable for human consumption.

Since the purpose of the egg is to produce young, the contents of the egg make up a well-balanced diet for the developing embryo. The eggshell is composed almost entirely of calcium carbonate. This provides the embryo with calcium for the formation of bones and for other body-building purposes.

Development of the bird's egg

The egg begins its development in the ovary of the female. Each reproductive cell is called an *ovum.* It is contained in a very thin envelope called the *follicle,* which is attached to the ovary by a slender stalk. Many ova are present in the ovary, and grow in size as the bird comes into laying condition. Yolk granules accumulate in layers within the ovum until the yolk of the egg becomes as large as that seen in the fresh-laid egg. At that stage of development the follicle bursts along a streak called the *stigma* and the yolk is freed from the ovary.

The yolk is picked up by the mouth of the oviduct, where production of the inside of the egg is completed. First, thick albumen surrounds the yolk. As the yolk travels through the oviduct, shell membranes are added. The egg spends the rest of its formation time in the uterus, where additional albumen is added and the shell is formed. Domestic hens require about 24 to 25 hours from the time the yolk enters the oviduct until the completed egg is laid. In most cases, the egg moves through the oviduct small end first, but is laid large end first.

Hens managed for commercial egg production lay at all times of the year. They are kept in a specially controlled environment that provides 14 to 16 hours of natural or artificial light. The ancestors of domestic hens, however, normally laid during the spring months only. Nearly all wild birds lay in the spring. Birds respond to the gradual increase in the amount of daylight or sunlight during the spring months. A tiny gland, the *pituitary,* located at the base of the brain, secretes hormones. These speed up the development of the ova. The action of light influences the activity of the pituitary gland. When the day length increases, more of the hormone is secreted. The hormone secretions are circulated throughout the blood, and stimulate the bird to start laying eggs.

How embryos develop

In mammals, snakes, turtles, and insects, mating takes place between the sexes and eggs are fertilized within the body of the female.

Toads and frogs also mate, but the eggs are fertilized after they are freed by the female. Frogs' eggs will develop into tadpoles if the surface of each egg is punctured with a very fine needle. The eggs of the sea urchin may also be made to develop without natural fertilization if they are treated with certain chemicals. Most fishes do not mate. The male deposits his reproductive cells near the eggs after they are laid.

In most mammals, the development of the embryo takes place within the body of the female until the young animal is born. But the duckbill platypus is a mammal which lays an egg with a large yolk and shell. The development of the embryo takes place outside the body of the female.

The fertilization of the bird's egg takes place in the upper part of the oviduct. Only one male cell fertilizes each female cell. The union of the male and female reproductive cells causes the development of the embryo. The fertilized cell begins to divide, and many cell divisions are completed before the egg is laid.

The egg of the domestic hen must be kept at the proper temperature or incubated for 21 days before the chicks will hatch. Most duck eggs incubate for 28 days, but Muscovy duck eggs require 35 days. Turkey and guinea eggs must be incubated for 28 days, goose eggs from 30 to 35 days, quail eggs 22 to 24 days, and pheasant eggs 23 to 28 days, depending on the variety. The eggs may be incubated under hens or in incubators.

Incubators have a constant temperature of around 99 or 100 °F (37 or 38 °C). The business of incubating chicken and turkey eggs in the United States has developed so widely that nearly all chickens and turkeys raised each year are hatched in commercial hatcheries. Some hatcheries hold over a million eggs.

At the time the egg is laid, the cells of the germ have already begun to divide and develop. At this stage, the germ is made up of two layers of cells. The outer layer is called the *ectoderm,* and the inner layer the *endoderm.* Under proper incubation, the cells continue to divide rapidly and the embryo begins to take shape. The two layers of cells soon become three layers. The *mesoderm* arises between the ectoderm and the endoderm. The ectoderm grows into the skin, feathers, and other external features, as well as the nervous system. The mesoderm grows into the bones, blood, muscles, and reproductive and excretory organs. The endoderm develops into the respiratory and secretory organs and the linings of the digestive tract.

The white of the egg serves as the principal source of nourishment for the embryo during the first two weeks. After this time, the yolk provides the necessary nourishment for the embryo's development.

Uses of eggs

Chicken eggs form an important part of the human diet in many countries of the world. In some areas, duck eggs are widely used, and in certain places eggs may be pickled or preserved. People in some countries consider the eggs of wild birds a delicacy. Turtle eggs are used in turtle soup, and fish eggs—especially shad roe—are highly prized as food.

Chicken eggs provide an excellent source of proteins, iron, and phosphorus. Egg yolk is a rich source of vitamins A and D, and the B vitamins. The albumen is a good source for most B vitamins. Chicken eggs also contain a fatty substance called *cholesterol.* Many physicians believe that too much cholesterol in a person's diet may contribute to heart disease (see **Cholesterol**).

White and brown eggs have the same food value. The U.S. Department of Agriculture classifies consumer eggs as Grade AA, A, and B. These standards are based on the condition of the shell, yolk, and white, and on the air cell size.

Eggs form the chief ingredient of omelets. They are also used in salads, cakes, cookies, casseroles, and other recipes. Frozen and dried eggs (egg solids) are important in baking and cooking.

Eggs are used for other purposes besides food. For example, they are used in vaccine preparation and for other laboratory purposes. Some animal feeds contain eggs. Eggs are also used in the production of adhesives, cosmetics, shampoos, and specialty inks and paints.

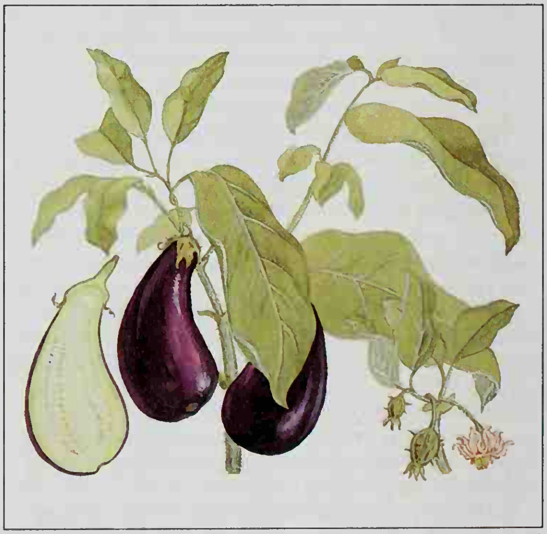
China ranks as the world's leading egg-producing nation, the United States ranks second, and Japan ranks third. For a list of the leading egg-producing states in the United States, see **Chicken** (graph: Leading egg-producing states). N. Paul Johnston

Related articles in ***World Book*** include:

Albumin
Bird (Laying and hatching eggs; pictures)
Caviar
Chicken
Easter (Easter eggs)
Embryo
Fish (How fish reproduce)
Insect (The life cycle of insects)
Poultry
Reproduction
Snake (picture: Snakes hatching from eggs)

Eggleston, *EHG uhl stuhn,* **Edward** (1837-1902), wrote *The Hoosier Schoolmaster* (1871), a fresh, delightful story of early Indiana. The book is one of the first attempts to write a story about American regional life in the West. *The End of the World* (1872) deals with the Millerites, a religious group that expected Christ's second coming in 1843. *The Graysons* (1887) shows Abraham Lincoln as a young lawyer. Eggleston was born on Dec. 10, 1837, in Vevay, Indiana. Besides being a writer, he was also a Methodist circuit rider and a historian. He died on Sept. 4, 1902. Bert Hitchcock

Eggplant is a plant that bears large egg-shaped fruit. The fruit also is called *eggplant* and sometimes *garden egg.* The purple variety of fruit has been a popular vegetable in the United States since about 1860, even though it has moderately low levels of vitamins and calories. Eggplants with white, brown, yellow, or striped fruits are used chiefly as ornaments. It is believed the first eggplant grew in northern India and later spread to China, Europe, and South America. Now eggplant grows in many tropical lands. The fruit grows on a bush that stands from 2 to 6 feet (61 to 180 centimeters) high. The fruit hangs among the grayish-green hairy leaves, and sometimes grows nearly as large as a football. It grows only in warm weather, and takes 115 to 120 days to



WORLD BOOK illustration by Kate Lloyd-Jones, Linden Artists Ltd.

The eggplant is a plant that produces large fruit shaped somewhat like an egg. The fruit is often served as a vegetable.

ripen. Where the warm season is too short, the seeds must be planted in a greenhouse. Then the seedlings are transplanted after warm weather begins. Little black flea beetles often attack eggplants and eat holes in the leaves. These beetles must be controlled in order to grow eggplants successfully. Albert Liptay

Scientific classification. The eggplant belongs to the nightshade family, Solanaceae. Its scientific name is *Solanum melongena.*

See also **Nightshade; Solanum.**

Eglantine, *EHG luhn tyn,* is a wild rose, commonly called *sweetbrier.* The plant grows as a shrub, and sometimes reaches a height of 6 feet (1.8 meters). It has curving brown stems covered with sharp, hooked prickles. Its small leaves grow close together. They are dark green on top and pale green underneath.

The flowers are a soft pink color. Both the leaves and blossoms have a sweet, spicy scent. The plant bears bright red or orange fruits. These fruits appear after the flowers have fallen. The eglantine originated in Europe. It grows in parts of the eastern United States. Eglantine is used in general landscaping for hedges or screen plantings. Walter S. Judd

Scientific classification. The eglantine belongs to the rose family, Rosaceae. It is *Rosa eglanteria.*

Ego, *EE goh,* is a term used in psychoanalysis to describe one of the three parts of the mind. The two other parts are the *id,* or instincts, and the *superego,* or conscience. The ego resolves conflicts among the individual's instinctual impulses, his or her sense of guilt, and the demands of external reality. For example, the ego regulates emotions and impulses that might not be acceptable to other people. The ego also governs such areas as memory, thought and decision making, walking and other voluntary movements, and perceptions, such as hearing, feeling, and sight.

Psychoanalysts sometimes use the word *ego* to mean a person's self. In popular usage, the word has come to mean selfishness, self-love, or self-esteem.

Allen Frances

See also **Psychoanalysis.**

Egret, *EE greht,* is any of eight species of birds in the heron family. The name *egret* comes from the French word *aigrette,* which means *heron.* Like other herons, egrets have long legs, a long neck, and a long, thin bill. Most egrets possess white feathers. During the mating season, egrets grow long plumes on the back, neck, and head. These plumes are sometimes called *aigrettes.*

Egrets live throughout much of the world, except for the Arctic and Antarctica. Adults range from 17 to 40 inches (43 to 102 centimeters) long and have a wingspread of up to 67 inches (170 centimeters).

In the late 1800's and early 1900's, egret plumes were prized as decorations for women's hats. Hunters killed great numbers of egrets for the plumes, and several species were threatened with extinction. Finally, countries passed laws to protect egrets from hunters, and fashions changed. As a result, the egret population has gradually increased.

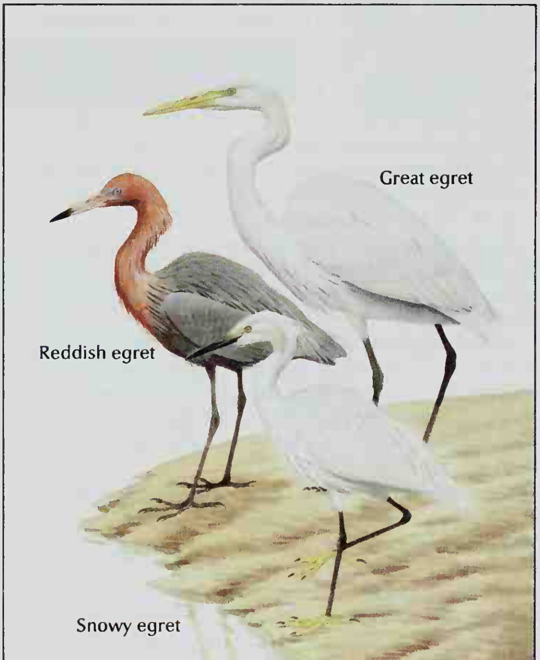
Kinds. In North America, the most commonly seen egret is the *great egret,* also called the *common egret.* The bird ranks as the largest egret. It is also found in South America and the Eastern Hemisphere. The *snowy egret,* a smaller species, lives mainly in the southern United States. It grows especially beautiful plumes. The *cattle egret* is one of the most widespread kinds. Until the mid-1800's, this bird lived chiefly in Africa. It now inhabits every continent except Antarctica. The *reddish egret* lives mainly along the Gulf Coast of the United States and in Mexico and the West Indies. It has two color forms. In one form, the bird is white. In the other, it has a reddish head and neck and a gray body. The *slaty egret* of Africa ranks as the smallest species of egret.

Habits. Most egrets live near water. They feed on fishes, frogs, and other animals found in or around water. To catch a prey, most egrets stand motionless in shallow water until the animal comes close to them. Then they quickly seize the animal with their bill. They also may slowly stalk a prey or try to chase it down. The cattle egret usually feeds on insects in upland areas. It often follows cattle, horses, or other grazing animals, preying on the insects those animals disturb.

Egrets often nest with other herons in large colonies that may include hundreds of members. Egrets build their nests in bushes or trees. The female usually lays three to five light-blue or light-green eggs. The young are covered with down when they hatch. Both parents care for the babies and bring them food. After the mating season, egrets often wander widely and may be seen in areas where they do not nest. James J. Dinsmore

Scientific classification. Egrets belong to the heron family, Ardeidae. The scientific name of the great egret is *Ardea alba;* the snowy egret is *Egretta thula;* the cattle egret is *Bubulcus ibis;* the reddish egret is *Egretta rufescens;* and the slaty egret is *Egretta vinaceigula.*

See also **Heron.**



WORLD BOOK illustration by Trevor Boyer, Linden Artists Ltd.

Egrets belong to the heron family. They have long legs, a long neck, and a long, thin bill. There are eight species. Three species found in the United States are shown here.

© Corbis

Cairo, Egypt's capital and largest city, is also the largest city in Africa and the largest city in the Middle East. The Nile River, the longest river in the world, flows northward through the Cairo metropolitan area. The river provides precious water for agriculture and industry.

Egypt

Egypt is a Middle Eastern country in the northeast corner of Africa. A small part of Egypt, the Sinai Peninsula, is in Asia. Little rain falls in Egypt, and dry, windswept desert covers most of the land. But the Nile River flows northward through the desert and serves as a vital source of life for most Egyptians. Almost all of Egypt's people live near the Nile or along the Suez Canal, the country's other important waterway.

Egypt is Africa's second largest country in population. Only Nigeria has more people. Cairo, Egypt's capital and largest city, is also the largest city in Africa.

Egypt's population has increased tremendously since the mid-1900's. In addition, many people have moved from rural villages to cities in search of work. As a result, the cities of Egypt overflow with people.

Most Egyptians consider themselves Arabs. More than 90 percent of Egyptians are Muslims. Islam, the Muslim religion, influences family life, social relationships, business activities, and government affairs. Al-Azhar University in Cairo is the world's leading center of Islamic teaching.

For thousands of years, floodwaters from the Nile deposited rich soil on the riverbanks. As a result, the Nile Valley and Delta region of Egypt contains extraordinarily fertile farmland. Agriculture provides jobs for more Egyptians than any other economic activity. Cotton is the most important agricultural export. Other crops grown in Egypt include corn, fruits, rice, sugar cane, and wheat.

Michael J. Reimer, the contributor of this article, is Associate Professor of History at the American University in Cairo.

Egypt has expanded a variety of manufacturing industries since the mid-1900's. Cement, cotton textiles, and processed foods are among the chief manufactured products. Petroleum provides much energy, as does hydroelectric power from the Aswan High Dam on the Nile River.

Egypt is a birthplace of civilization. The ancient Egyptians developed a great culture about 5,000 years ago. They created the first national government, as well as early forms of mathematics and writing. For the story of this civilization, see **Egypt, Ancient.**

Egypt's hot, dry climate has helped preserve many

Facts in brief

Capital: Cairo.
Official language: Arabic.
Official name: Arab Republic of Egypt.
Area: 386,662 mi^2 (1,001,449 km^2). *Greatest distances*—east-west, 770 mi (1,240 km); north-south, 675 mi (1,086 km). *Coastline*—Mediterranean Sea, 565 mi (909 km); Red Sea, 850 mi (1,370 km).
Elevation: *Highest*—Jabal Katrinah, 8,651 ft (2,637 m) above sea level. *Lowest*—Qattara Depression, 436 ft (133 m) below sea level.
Population: *Estimated 2002 population*—70,818,000; population density, 183 per mi^2 (71 per km^2); distribution, 56 percent rural, 44 percent urban. *1996 census*—59,272,382.
Chief products: *Agriculture*—corn, cotton, dates, oranges, potatoes, rice, sugar cane, tomatoes, wheat. *Manufacturing*—cement, chemicals, cotton textiles, fertilizers, motor vehicles, processed foods, steel. *Mining*—petroleum.
National anthem: "Beladi, Beladi" ("My Country, My Country").
Money: *Basic unit*—pound. One hundred piasters equal one pound.

products of ancient Egyptian culture. Tourists from all over the world travel to Egypt to see such wonders as the Great Sphinx, an enormous stone sculpture with the head of a human being and the body of a lion. They can also marvel at the huge pyramids that the ancient Egyptians built as tombs for their *pharaohs* (rulers).

After ancient times, Egypt was ruled by a series of foreign invaders. In 1953, Egypt became an independent republic. Since then, it has played a leading role in the Middle East, especially in Arab affairs. Egypt's official name is the Arab Republic of Egypt.

Government

Egypt is a republic with a strong national government. According to the Constitution adopted in 1971, Egypt is a democratic and socialist society, and Egyptians are part of the Arab nation.

National government. Egypt's national government has three branches. They are (1) an executive branch headed by a president, (2) a legislative branch called the People's Assembly, and (3) a judicial branch, or court system.

The president serves as the center of power in Egypt. A candidate for president must be nominated by at least one-third of the members of the People's Assembly and confirmed by at least two-thirds of the members. The people then vote the candidate into office in a public referendum. Only one candidate is presented to the people. Egypt's president may serve an unlimited number of six-year terms.

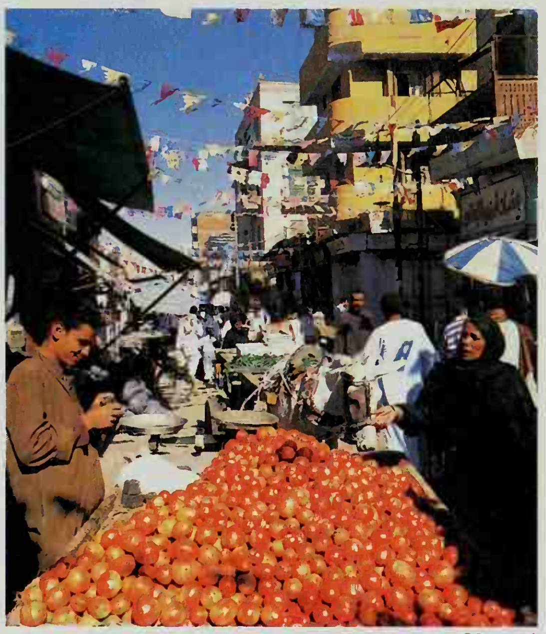
The president may appoint one or more vice presidents, as well as the members of the Council of Ministers (cabinet). In turn, the central government selects all local administrators. Thus, the president has great influence and authority at all levels of government. The president also commands Egypt's armed forces.

The People's Assembly has 444 members elected by Egyptian voters. The president may appoint 10 more members. All members serve five-year terms. At least half the members must be workers or farmers. In theory, the People's Assembly has great lawmaking powers. In practice, the Assembly generally does little but approve the president's policies.

Local government. Egypt is divided into 27 political units called *governorates*. A governor appointed by the president heads each governorate. The governorates are divided into districts and villages, which also are run by appointed officials. Elected councils at each level of local government assist the appointed leaders.

Politics. The National Democratic Party is Egypt's largest political party. The president and most top government officials belong to this party. The National Democratic Party supports a mixture of public and private ownership, and strong ties with Western countries. Opposition parties may participate in general elections. Such parties include the New Wafd and Socialist Labor parties. All Egyptian citizens aged 18 or older may vote.

Courts. The Supreme Constitutional Court is the highest court in Egypt. Lower courts include appeals courts, *tribunals of first instance* (regional courts), and district courts. The president appoints judges on the recommendation of the minister of justice. The courts are otherwise independent of presidential control or influence. There are no juries in Egypt's court system.



© Superstock

Outdoor marketplaces called *suqs* are found in many Egyptian cities and towns. Many people enjoy going to suqs to make purchases, visit with friends, and relax.

Symbols of Egypt include the flag, *above left*, and the coat of arms, *above right*. The eagle is a symbol of Saladin, a Muslim leader who lived during the 1100's. The eagle's claws hold a panel bearing the country's name.

WORLD BOOK map

Egypt lies mainly in the northeast corner of Africa, bordered by the Mediterranean Sea, Israel, the Red Sea, Sudan, and Libya.

Egypt map index

Cities and towns

Abnub	48,519	C	4
Abu Tij	48,711	D	4
Abu Zanimah		B	5
Abu Kabir*	69,509	B	4
Ad Dabah		B	3
Akhmim	70,602	D	4
Al Arish	67,638	A	5
Al Badari	34,858	D	4
Al Balyana	33,579	D	4
Al Bawiti		C	3
Alexandria (Al Iskan-dari yah)	3,380,000	A	3
Al Fashn	43,347	C	4
Al Fayyum	250,000	B	4
Al Ghurdaqah	22,801	C	5
Al Hawami-diyah*	73,060	B	4
Al Iskandariyah, see Alexandria			
Al Jamaliyah	45,157	A	4
Al Jizah, see Giza			
Al Kharijah	38,544	D	4
Al Mahallah al Kubra	408,000	A	4
Al Manshah	37,788	D	4
Al Mansurah	371,000	A	4
Al Manzilah*	55,090	A	4
Al Matariyah	74,554	A	4
Al Minya	208,000	C	4
Al Qahirah, see Cairo			
Al Qasr		D	3
Al Qusaymah		B	6
Al Qusayr	19,997	D	6
Al Qusiyah	42,175	C	4
An Nakhl		B	5
Armant	54,650	D	5
Ashmun*	54,450	B	4
Ash Shabb		F	3
As Sallum		A	1
As Sinbilla-wayn*	60,285	B	4
Aswan	220,000	E	5
Asyut	321,000	D	4
At Tur		C	5
Ayn Dallah		C	2
Ayn Sukhnah		B	5
Az Zaqaziq	287,000	B	4
Baltim		A	4
Banha	136,000	B	4
Bani Mazar	47,964	C	4
Bani Suwayf	179,000	B	4
Baris		E	4
Bilbays	96,540	B	4
Bilqas Qism Awwal*	73,162	A	4
Bir Abu al Husayn		F	3
Bir Jifjafah		B	5
Bir Misahah		F	2
Bir Sahra Biyala*	40,000	A	4
Bur Salajah		D	5
Bur Said, see Port Said			
Cairo (Al Qahirah)	6,800,000	B	4
Damanhur	222,000	A	4
Damietta (Dumyat)	89,498	A	4
Dayrut	44,498	C	4
Dhahab		C	6
Dikirnis*	48,667	A	4
Dishna	37,978	D	5
Disuq*	78,119	A	4
El Alamein		A	3
Faqus*	48,625	B	4
Giza (Al Jizah)	2,144,000	B	4
Hawsh Isa*	53,619	B	3
Hihya*	29,334	B	4
Idfu	45,737	E	5
Idku*	70,729	A	3
Ismailia	255,000	B	5
Isna	43,055	E	5
Jamsah		C	5
Jirja	67,777	D	4
Kafr ad Dawwar	226,000	A	3
Kafr ash Shaykh*	102,910	A	4
Kafr az Zayyat*	58,061	B	4
Kawm Umbu	52,131	E	5
Luxor	146,000	D	5
Maghaghah	50,807	C	4
Mallawi	99,062	C	4
Manfalut	52,644	C	4
Marsa al Alam		E	6
Matruh	43,192	A	2
Minuf*	69,883	B	4
Mit Ghamr*	93,253	B	4
Mut	11,899	D	3
Nabq		C	6
Naj Hammadi	28,493	D	5
Nasr*	54,482	B	3
Port Said (Bur Said)	460,000	A	5
Qalyub	86,684	B	4
Qasr al Farafirah		D	2
Qina	141,000	D	5
Qus	42,467	D	5
Ras as Sidr		B	5
Ras Gharib	20,617	C	5
Rosetta (Rashid)	52,014	A	3
Samalut	62,404	C	4
Sharm ash Shaykh		C	6
Shibin al Kawm	158,000	B	4
Shubra al Khaymah	834,000	B	4
Sidi Barrani		A	1
Sinnuris	55,323	B	4
Siwah		B	1
Suez	388,000	B	5
Suhaj	156,000	D	4
Tahta	58,516	D	4
Tanta	380,000	A	4
Tel al-Kabir (At Tall al Kabir)*		B	4
Tima	47,223	D	4
Zafaranah		B	5
Zifta*	69,050	B	4

*Does not appear on map; key shows general location.

Places listed without populations have less than 10,000 people; populations for these places not available.

Sources: 1992 official estimates for largest cities, 1986 census for other cities

Armed forces. Egypt maintains a large military, consisting of an army, a navy, an air force, and an air defense command. About 450,000 people serve in Egypt's armed forces. In addition, the country's military reserves have about 250,000 members. Men between the ages of 18 and 30 may be drafted for three years of military service.

People

About 99 percent of all Egyptians live along the Nile River and the Suez Canal, in an area that covers only about 4 percent of Egypt's total land. The rest of the country's people live in the deserts and mountains east and west of the Nile.

Most Egyptians consider themselves Arabs (see **Arabs**). Bedouins make up a distinct cultural minority among the Arab population. Bedouins are *nomads* (wanderers) who live in small groups in the Egyptian deserts. Most former Bedouins have settled and become farmers, but some wandering tribes remain.

The Nubians make up the largest non-Arab minority in Egypt. These people originally lived in villages along the Nile in northern Sudan and the extreme south of Egypt, in a region called the Nubian Valley. Construction of the Aswan High Dam in the 1960's forced the Nubians to move north along the Nile.

Ancestry. Since ancient times, numerous groups of people have invaded Egypt and have intermarried with native Egyptians. As a result, present-day Egyptians can trace their ancestry not only to ancient Egyptians, but also to such groups as Arabs, Ethiopians, Persians, and Turks, as well as Greeks, Romans, and other Europeans.

Language. Arabic is the official language of Egypt. Regional Arabic dialects have different sounds and words. The dialect of Cairo is the most widely spoken dialect throughout Egypt. The Bedouin dialects differ from those spoken by the settled residents of the Nile Valley. People in some desert villages speak Berber rather than Arabic. Many educated Egyptians speak English or French as a second language. See **Arabic language.**

Way of life

Lifestyles in Egypt's cities differ greatly from those in its villages. Egyptian city dwellers cope with such typical urban problems as housing shortages and traffic congestion. Although many live in poverty, others enjoy modern conveniences and government services that the cities offer.

Rural life changed greatly during the 1900's. Many jobs in rural areas are now done with the help of machines. But much work is still done by hand, and donkeys, water buffaloes, and camels continue to be used for some heavy tasks. For people throughout Egypt, the beliefs and traditions of Islam form a unifying bond.

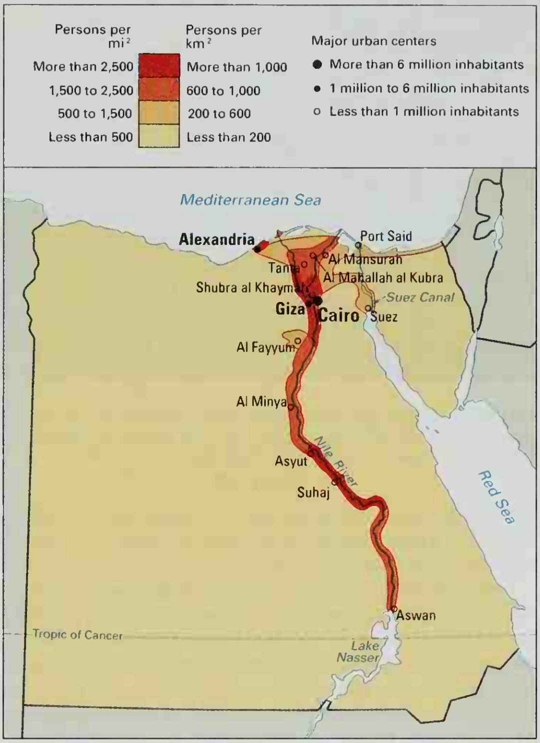
City life. Cairo is Egypt's largest city and the largest city in Africa. The port city of Alexandria is Egypt's second largest city. Cities in Egypt are overcrowded. Traffic moves slowly, and public transportation is inadequate. Riders crowd onto streetcars and trains.

Great extremes of wealth and poverty characterize Egyptian cities. Attractive residential areas exist beside vast slums. Lack of sufficient housing is a serious problem. Many people crowd into small apartments. Many more build makeshift huts on land that belongs to other

Population density

The population distribution of Egypt is extremely uneven. The vast majority of the people live along the Nile River and its delta. Egypt's deserts are thinly populated.

WORLD BOOK map



people, or on the roofs of apartment buildings. Some of the poorest people in Cairo take refuge in historic tombs on the outskirts of the city, in an area known as the City of the Dead.

The cities provide a variety of jobs. Educated Egyptians work in such professions as business and government. Workers with little or no education find jobs at factories or as unskilled laborers.

Rural life. Until the 1900's, the vast majority of Egyptians lived in the countryside. Today, more than half of Egypt's people still live in rural areas. Almost all of them are peasants called *fellahin.* They live in villages along the Nile River or the Suez Canal. Most of the fellahin farm small plots of land or tend animals. Many fellahin do not own land. They rent land or work as laborers in the fields of more prosperous landowners. A small minority of Egypt's rural people are Bedouins who wander the deserts with their herds of camels, goats, and sheep.

The traditional village home used to be a simple hut built of mud bricks with a straw roof. Most huts consisted of one to three rooms, with few furnishings, and a courtyard. Today, many village homes are made of fired bricks or concrete, and they are larger and more comfortable than in the past. Electric power is commonly available, as are televisions, radios, and cassette recorders. Many villages have gained wealth from the earnings of fellahin who have worked outside Egypt, especially in the rich Arab countries of the Persian Gulf. The spread

© Norman Owen Tomalin, Bruce Coleman Collection

Farmers in Egypt include peasants called *fellahin.* Many fellahin farm small plots of land in the fertile valley along the Nile River and in the river's low-lying delta. The farmworkers shown here are tending crops near Luxor.

© Thomas Nebbia, Woodfin Camp, Inc.

Some parts of Cairo house many poor people. Egypt's crowded cities lack enough housing for the growing population.

of education and health services has also improved the lives of villagers. However, illiteracy, disease, and poverty remain major problems in rural areas.

Each member of a village family performs certain duties. The husband organizes the planting, weeding, and harvesting of crops. The wife cooks, carries water, and helps in the fields. Children look after the animals and help bring water to the fields.

Egyptian villages are characterized by a strong sense of community. People come together to celebrate feasts, festivals, marriages, and births. Islam, the religion of most Egyptians, provides a strong unifying bond. *Mosques* (Islamic houses of worship) serve as centers of both religious and social life.

Clothing. Styles of clothing in Egypt reflect the different ways of life. Many well-to-do city dwellers wear clothing similar to that worn in the United States and Europe. Rural villagers and many poor city dwellers wear traditional clothing. Fellahin men wear pants and a long, full shirtlike garment called a *galabiyah.* Women wear long, flowing gowns in dark or bright colors.

Some Egyptians follow Islamic customs in their appearance. Men grow beards and wear long, light-colored gowns and skullcaps. Women wear robes and cover their hair, ears, and arms with a veil.

Food and drink. Most villagers and poor city dwellers in Egypt eat a simple diet based on bread and *ful* or *fool* (broad beans). At a typical evening meal, each person dips bread into a large bowl of hot vegetable stew.

Government-run stores in the cities distribute such food as meat, cheese, and eggs at controlled prices. However, supplies at these stores often run out. The well-to-do city people have more varied diets. They can afford to buy large quantities of meat and imported fruits and vegetables.

Sweetened coffee and tea are favorite beverages throughout Egypt. People also drink the milk of goats, sheep, and water buffaloes.

Recreation. Soccer is popular in Egypt. Many people attend matches or watch their favorite teams on television. But the main form of recreation in both cities and villages is socializing. People enjoy going to the *suq* (outdoor marketplace) to make purchases and to visit with friends. They like to sit and talk while drinking cups of coffee or tea, or relax by smoking a kind of water pipe known as a *shisha.*

Religion. Islam is the official religion of Egypt. More than 90 percent of the Egyptian people are Muslims—followers of Islam. Almost all of them follow the Sunni branch of Islam. Coptic Christians make up the largest religious minority group in Egypt.

Islam influences many aspects of life in Egypt. Religious duties include praying five times a day, *almsgiving* (giving money or goods to the poor), fasting, and, if possible, making a pilgrimage to Mecca, Saudi Arabia, the sacred city of Islam. Muslim traditions also affect government and law. For example, the government collects contributions from the wealthy and gives the money to the poor to fulfill the almsgiving requirement of Islam.

The government officially controls Islam in Egypt, and it appoints major Muslim religious leaders. In villages and city neighborhoods, some Muslims form brotherhoods and hold festivals and ceremonies outside of official control. Some of these groups use force in opposing the government and its religious leaders, whom they view as corrupted by non-Islamic values.

By law, Coptic Christians and other religious minorities may worship freely. But some radical Muslim groups have committed acts of violence against the Coptic community in Cairo and in parts of southern Egypt. See **Copts; Islam; Mosque; Muslims.**

Education. About half of Egypt's adult population can read and write. Illiteracy is highest in rural areas. The government is working to improve the quality and availability of education. For the country's literacy rate, see **Literacy** (table: Literacy rates for selected countries).

According to law, all children from ages 6 up to 14 must go to school. But in some places, schools are so

crowded that students go for only part of each day to make room for other students. Many teachers provide tutoring services outside school. Education at public elementary and high schools and public colleges is free. Egypt also has many private schools and a few private universities.

Cairo University is the largest institution of higher learning in Egypt. Al-Azhar University, one of the world's oldest universities, was founded around A.D. 970. It is a center of Islamic scholarship.

Egypt's educational system has problems from the elementary through the university level because of overcrowding and lack of funds. There is a shortage of teachers and school buildings, especially in rural areas. Despite these problems, Egypt's university graduates are among the best trained in the Arab world.

The arts. Egypt has a rich artistic tradition. Ancient Egyptians created many fine paintings and statues. They also produced and enjoyed music and stories. For more information about the arts of ancient Egypt, see **Egypt, Ancient** (Painting and sculpture; Music and literature).

Today, Egypt ranks as a center of the Arab publishing and motion-picture industries. The celebrated works of Egyptian writers and filmmakers have spread Egypt's culture throughout the Arab world. During the mid-1900's, the works of such writers as Tawfiq al-Hakim and Taha Hussein realistically described Egyptian and Arab society. In 1988, the Egyptian author Naguib Mahfouz became the first Arabic-language writer to win the Nobel Prize in literature.

Egyptians enjoy traditional and classical music, as well as modern Egyptian and Western music. Egypt's most popular singer of the 1900's, Um Kulthum, blended Eastern and Western themes in her songs.

© Catherine Osborne, Photo Researchers

Styles of clothing in Egypt vary. Many Egyptians wear clothing similar to that worn in North America and Europe. Others, such as the woman wearing a headscarf, follow Islamic custom.

© Josef Polleross, The Image Works

Muslims pray at a *mosque* (Islamic house of worship) in Cairo. Islam, the Muslim religion, is the official religion of Egypt. Most Egyptians follow the Sunni branch of Islam.

The land

Egypt consists mostly of sparsely settled deserts. But the inhabited areas—along the Nile River and the Suez Canal—are densely populated.

Egypt has four major land regions: (1) the Nile Valley and Delta, (2) the Western Desert, (3) the Eastern Desert, and (4) the Sinai Peninsula.

The Nile Valley and Delta region extends along the course of the Nile River, which measures about 1,000 miles (1,600 kilometers) in Egypt. The Nile flows northward into Egypt from Sudan to Cairo. Just north of Cairo, the river splits into two main branches and forms a delta. The Nile River delta measures about 150 miles (240 kilometers) at its base along the Mediterranean Sea, and about 100 miles (160 kilometers) from north to south. See **Nile River; Delta.**

The valley and delta region contains most of Egypt's farmland. Without the precious waters of the Nile, Egypt would be little more than a desert wasteland. For thousands of years, annual floods of the Nile deposited valuable soils upon the narrow plain on either side of the river and upon the low-lying delta. Almost all of Egypt's people live in the valley and delta region. Many of them farm its fertile soil.

In the southern part of the valley, the Aswan High Dam provides water for irrigation of the lands along the Nile. It also prevents severe damage from the Nile's annual flooding. Lake Nasser, a huge lake created behind the dam, catches and stores the floodwaters. The Aswan High Dam allows Egyptians to cultivate usable farmland more thoroughly. But the dam also collects a great deal of valuable soil. As a result, this soil is no longer deposited on the farmland that borders the Nile. See **Aswan High Dam; Lake Nasser.**

The Western Desert, also called the *Libyan Desert,* is part of the huge Sahara that stretches across northern Africa. It covers about two-thirds of Egypt's total area. The Western Desert consists almost entirely of a large, sandy plateau with some ridges and basins, and pit-shaped areas called *depressions.* The Qattara Depres-

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The Nile Valley and Delta region has most of Egypt's usable farmland. A narrow plain on either side of the river has extremely fertile soil. Barren desert lies beyond the farmland.

© Albano Guatti, Corbis Stock Market

The Western Desert covers about two-thirds of Egypt's total area. It consists mainly of a large, sandy plateau. Scattered oases support small villages in the desert.

sion, Egypt's lowest point, drops 436 feet (133 meters) below sea level. It contains salty marshes, lakes, and *badlands* (regions of small, steep hills and deep gullies). Small villages occupy scattered oases in the desert.

The Eastern Desert, or *Arabian Desert,* is also part of the Sahara. The desert rises eastward from the Nile as a sloping, sandy plateau for about 50 to 80 miles (80 to 130 kilometers). It then turns into a series of rocky hills and deep valleys called *wadis.* The land in this region is virtually impossible to cultivate. As a result, the Eastern Desert is mostly uninhabited, except for a few villages on the coast of the Red Sea.

The Sinai Peninsula is a desert area that lies east of the Suez Canal and the Gulf of Suez. It consists of a flat, sandy coastal plain in the north, a high limestone plateau in the central area, and mountains in the south. Egypt's highest point, Jabal Katrinah, rises 8,651 feet (2,637 meters) above sea level in the southern Sinai. Though desolate, the Sinai Peninsula has valuable oil deposits. About 300,000 people live on the peninsula.

Physical features

Abu Ballas*	D	2
Arabian Desert	C	3
Aswan High Dam	D	3
Bahriyah Oasis	B	2
Birkat Qarun (lake)	B	3
Dakhilah Oasis	D	2
Damietta Branch	A	3
Farafirah Oasis	C	2
Foul Bay	D	5
GhurdAbu Muharrik (dune)	C	2
Great Bitter Lake	B	3
Great Sand Sea	C	1
Gulf of Aqaba	B	4
Gulf of Suez	B	3
Hadabat al Jilf al Kabir (plateau)	E	1
Jabal at Tih (plateau)	B	4
Jabal Hamatah*	D	4
Jabal Kamil*	E	1
Jabal Katrinah*	B	4
Jabal Nugrus*	D	4
Jabal Shaib al Banat*	C	4
Jazirat Shakir (island)	C	4
Kharijah Oasis	D	3
Khalij as Sallum (bay)	A	1
Lake Burullus	A	3
Lake Manzilah	A	3
Lake Nasser	E	3
Libyan Desert	D	1
Libyan Plateau	A	1
Maaza Plateau	C	3
Mediterranean Sea	A	2
Mount Sinai (Jabal (Musa)*	B	4
Nile River	B	3
Nile Delta	A	3
Qattara Depression	B	2
Ras al Kanais (cape)	A	2
Ras Banas (cape)	D	4
Ras Muhammad (cape)	C	4
Red Sea	D	5
Rosetta Branch	B	3
Sabkhat al Bardawil (marsh)	A	4
Sahara (desert)	D	1
Siwah Oasis	B	1
Strait of Jubal	C	4
Suez Canal	A	3
Wadi al Allaqi†	E	4
Wadi al Kharit†	D	4
Wadi at Tarfa†	B	3
Wadi Jabjabah†	E	3

*Mountain.
†Dry stream.

© Kevin Fleming, Woodfin Camp, Inc.

The Sinai Peninsula is a desolate desert region in northeast Egypt. Its terrain includes a sandy coastal plain, a high limestone plateau, and mountains.

Climate

Egypt has a hot, dry climate with only two seasons—scorching summers and mild winters. Summer lasts from around May to October, and winter lasts from around November to April. January temperatures range from an average high of 65 °F (18 °C) in Cairo to an average high of 74 °F (23 °C) in Aswan. July temperatures reach an average high of 96 °F (36 °C) in Cairo, and 106 °F (41 °C) in Aswan. Daily temperatures in the deserts vary greatly. The average daytime high temperature is 104 °F (40 °C), while the temperature may drop to 45 °F (7 °C) after sunset. North winds from the Mediterranean Sea cool the coast of Egypt during the summer, so many wealthy Egyptians spend the hot summer months of July and August in Alexandria.

Most of Egypt receives little rain. Winter rainstorms occasionally strike the Mediterranean coast, where about 8 inches (20 centimeters) of rain fall each year. Inland, rainfall decreases. Annual rainfall in Cairo averages about 1 inch (2.5 centimeters). Southern Egypt receives only a trace of rain each year.

Around the month of April, a hot windstorm called the *khamsin* sweeps through Egypt. Its driving winds blow large amounts of sand and dust at high speeds. The khamsin may raise temperatures as much as 68 Fahrenheit degrees (38 Celsius degrees) in two hours, and it can damage crops.

Economy

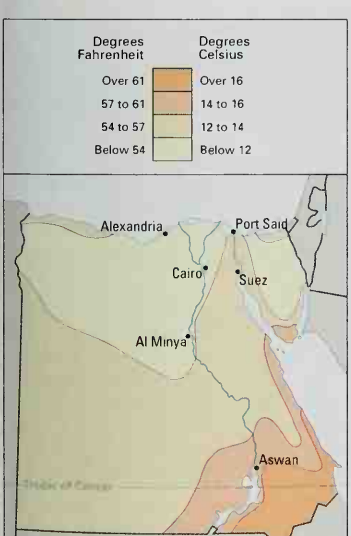
Egypt is a developing country with a number of economic problems. For example, Egypt must import much of its food supply to feed its increasing population. At the same time, its petroleum exports have been reduced

Average monthly weather

Cairo	Temperatures °F High	°F Low	°C High	°C Low	Days of rain or snow	Aswan	Temperatures °F High	°F Low	°C High	°C Low	Days of rain or snow
Jan.	65	47	18	8	1	Jan.	74	50	23	10	0
Feb.	69	48	21	9	1	Feb.	78	52	26	11	0
Mar.	75	52	24	11	1	Mar.	87	58	31	14	0
Apr.	83	57	28	14	0	Apr.	96	66	36	19	0
May	91	63	33	17	0	May	103	74	39	23	1
June	95	68	35	20	0	June	107	78	42	26	0
July	96	70	36	21	0	July	106	79	41	26	0
Aug.	95	71	35	22	0	Aug.	106	79	41	26	0
Sept.	90	68	32	20	0	Sept.	103	75	39	24	0
Oct.	86	65	30	18	0	Oct.	98	71	37	22	0
Nov.	78	58	26	14	1	Nov.	87	62	31	17	0
Dec.	68	50	20	10	1	Dec.	77	53	25	12	0

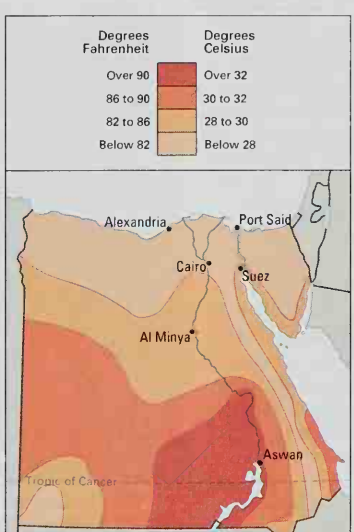
Average January temperatures

Temperatures in Egypt are mild during winter. The southeast has the warmest winter temperatures.



Average July temperatures

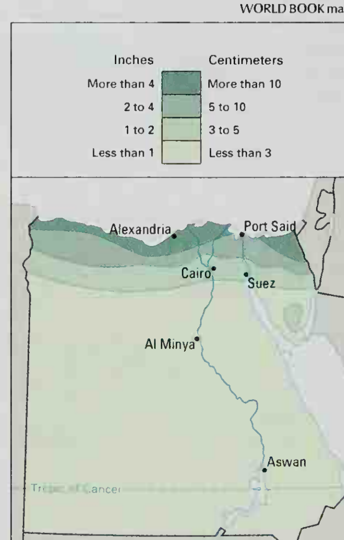
Most of Egypt has hot summers, but winds from the Mediterranean Sea cool the northern coast.



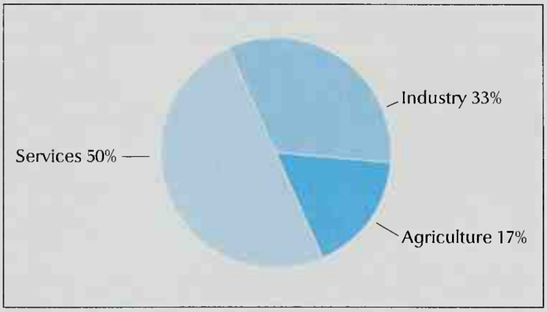
Average yearly precipitation

Little rain falls throughout most of Egypt. But winter rainstorms sometimes strike the Mediterranean coast.

WORLD BOOK maps



Gross domestic product



Egypt's gross domestic product (GDP) was $79,220,000,000 in 1998. The GDP is the total value of goods and services produced within a country in a year. *Services* include community, government, and personal services; finance, insurance, and real estate; transportation and communication; and wholesale and retail trade. *Industry* includes construction, manufacturing, mining, and utilities. *Agriculture* includes agriculture and fishing.

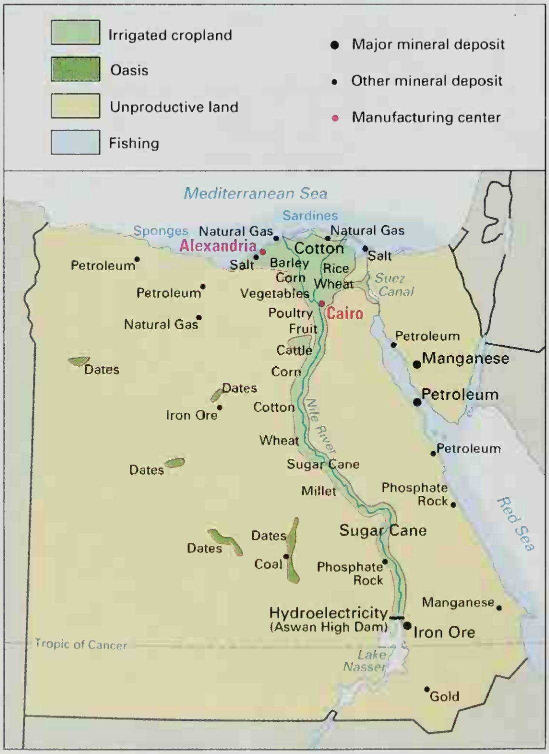
because of increased demand within the country. Thus, Egypt faces a foreign debt, as the cost of its imports far exceeds its income from exports.

During the 1950's and 1960's, the government of Egypt took over almost all large-scale business and industry. Farms and small businesses remained privately owned.

Economy of Egypt

Agriculture is an important economic activity in Egypt's Nile Valley and Delta region. This map shows the country's major farm products and indicates its chief mineral deposits.

WORLD BOOK map



Production and workers by economic activities

Economic activities	Percent of GDP produced	Employed workers: Number of people	Employed workers: Percent of total
Manufacturing & mining	25	2,111,200	13
Trade, restaurants, & hotels	19	2,226,900	14
Agriculture & fishing	17	4,822,700	30
Community, government, & personal services	16	4,136,200	25
Transportation & communication	9	954,100	6
Finance, insurance, & real estate	6	440,500	3
Construction	5	1,287,100	8
Utilities	2	203,400	1
Total	100	16,182,100	100

Figures are for 1998.
Sources: International Labour Office; International Monetary Fund.

Today, government ownership continues to dominate in most major industries, such as food processing, textiles, and steel. However, the government has tried to encourage more private investment in the production of goods and services.

Service industries are economic activities that provide services rather than produce goods. Such industries have become increasingly important to the Egyptian economy. Today, services account for about half of Egypt's gross domestic product (GDP) and employ almost half its workers. The GDP is the total value of all goods and services produced within a country in a year. Many Egyptians work in such services as banking, government, and trade. Other important services include transportation, communication, and education.

Manufacturing accounts for about a fourth of Egypt's GDP and employs about an eighth of the Egyptian labor force. Manufacturing has expanded rapidly in Egypt since the 1950's, when the government took a leading role in promoting industrialization. Egypt's government owns and operates most of the country's large and medium-sized businesses.

Food processing and textile production are among the most important industries. Egypt also manufactures cement, chemicals, fertilizers, motor vehicles, and steel. Cairo and Alexandria are the leading manufacturing centers.

Agriculture accounts for only about a sixth of Egypt's GDP. But it employs nearly a third of the country's workers. Egypt has about 8 million acres (3.2 million hectares) of farmland, almost all of it along the Nile. About 90 percent is privately owned. Average farm size in Egypt is only about 2 acres (0.8 hectare).

For centuries, Egyptian farmers relied on the annual floods of the Nile River to irrigate their fields and renew the topsoil. Each year, before the Nile flooded in July and August, farmers created a series of basins on surrounding farmland. When the Nile overflowed, these basins trapped the floodwaters and the *silt* (tiny particles of soil) that they carried. After the floodwaters withdrew, farmers planted their fields.

Beginning in the 1800's, Egyptians replaced the basin irrigation system with a system of year-round irrigation. They built dams, canals, and reservoirs to capture Nile

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Giant pyramids and other ancient wonders of Egypt attract visitors from all over the world. The pyramids shown here are at Giza, west of Cairo. They were built about 2600 to 2500 B.C. They stand at Giza, just west of Cairo.

water and make it available throughout the year. The changeover was completed with the building of the Aswan High Dam, which began operation in 1968. The dam has increased the amount of land irrigated all year by about $2\frac{1}{4}$ million acres (910,000 hectares). Today, nearly all of Egypt's farmland has continuous irrigation. As a result, farmers can plant crops the year around.

Cotton is Egypt's most valuable cash crop, and Egypt is one of the world's leading cotton producers. Egypt leads all countries in the production of high quality *long-staple* (long-fibered) cotton. Such cotton is known for its strength and durability. Egypt greatly increased its export of cotton during the American Civil War (1861-1865), when the Union blockade of ports interrupted cotton exports from the Southern States of America.

The Egyptian government requires farmers to use some land for growing food crops to feed the expanding population. Important crops include corn, potatoes, rice, sugar cane, tomatoes, wheat, and fruits, such as apples, bananas, grapes, oranges and other citrus fruits, and watermelons. Egypt leads the world in the production of dates, which are grown mainly in the desert oases. Goats and sheep are raised for meat, milk, and wool. Cattle and water buffaloes, kept chiefly as work animals, also provide some milk. A large number of farmers raise chickens for meat and eggs.

© Superstock

The manufacturing of textiles ranks as one of Egypt's most important industries. Egypt is one of the world's leading cotton producers, and cotton is Egypt's most valuable cash crop.

Mining. Egypt's most important minerals are petroleum and natural gas. Oil is found in the Eastern and Western deserts, the Sinai Peninsula, and offshore in the Gulf of Suez and the Red Sea. Natural gas is plentiful near Alexandria, in the Delta, and in the Western Desert. Egypt also has some valuable deposits of iron ore, manganese, and phosphate rock.

Tourism. Egypt's warm, dry climate and its beautiful relics from ancient times attract visitors from all over the world. Large numbers of people travel to Egypt to admire such wonders as the giant pyramids and the Great Sphinx at Giza. Near Luxor, ancient tombs in the Valley of the Kings and magnificent temples draw many tourists. Visitors to the city of Cairo admire its beautiful mosques, city walls and gates, and traditional Islamic architecture. Egypt's Red Sea resorts attract growing numbers of visitors, who come to enjoy the sunny beaches and spectacular coral reefs. But since the 1990's, Egypt's tourism industry has suffered greatly because of visitors' fears of terrorism. See **Pyramids; Sphinx; Valley of the Kings.**

Energy sources. Petroleum provides most of Egypt's energy. Natural gas is also an important power source. The hydroelectric plant of the Aswan High Dam generates a large amount of low-cost electric power (see **Aswan High Dam**).

International trade. Egypt imports more goods than it exports. Imports include food, machinery, and transportation equipment. Egypt's major suppliers of imports are France, Germany, Italy, Japan, and the United States. Egyptian exports include cotton fibers and products, fruits, and petroleum. Major markets for exports include Germany, Italy, and the United States.

Transportation and communication. For thousands of years, the Nile River was the primary means of transportation within Egypt. Today, transportation takes

© Carl Purcell

The Aswan High Dam captures water from the Nile River and makes it available for year-round farming. The dam's hydroelectric plant generates much electric power at low cost.

many forms. Roads and railroads connect all important cities and towns. Two main highways link Alexandria and Cairo. One highway stretches across the desert, and the other passes through the densely populated Nile Delta. People use various forms of local transportation. Buses, cars, and motorcycles share Egypt's roads with bicycles, donkeys, and carts. Only a small percentage of Egypt's people own automobiles.

Cairo has an international airport where many airlines provide service to major cities of the world. Egypt's government-run airline, EgyptAir, provides service throughout the country and to and from foreign cities. Alexandria, on the Mediterranean Sea, ranks as Egypt's leading port. The country's two other major ports, Port Said and Suez, lie on the Suez Canal.

Cairo serves as the center of Egypt's communications industries. Egypt has more than 15 daily newspapers. The three most important papers—*Al-Ahram, Al-Akhbar,* and *Al-Jumhuriyah*—circulate throughout the major cities and into the countryside. Although the government does not allow complete freedom of expression, a number of newspapers express political dissent. The Egyptian government owns and controls the nation's radio and television stations. Egypt has an average of about 1 radio for every 3 people and 1 television set for every 9 people.

History

Egypt's long, colorful history goes back more than 5,000 years to about 3100 B.C. For the story of Egypt until it was conquered by Muslim Arab armies between A.D. 639 and 642, see **Egypt, Ancient** (History).

Muslim rule. In A.D. 639, Arab Muslims, inspired by the birth of Islam, burst out of Arabia and invaded Egypt. At the time, Egypt was a province of the Byzantine, or East Roman, Empire. The Arabs captured Alexandria, which was then the capital of Egypt, in 642. Their commander, Amr ibn al-As, established a military camp and settlement in what is now part of Cairo. The Arab conquest transformed Egypt. The Egyptian people gradually adopted the Arabic language, and many converted from the Coptic Christian religion to Islam. See **Muslims.**

Egypt became an important province of the Islamic empire, which was ruled by Arab Muslim leaders called *caliphs.* Caliphs of the Umayyad *dynasty* (family of rulers) governed Egypt from Damascus (now the capital of Syria). They were followed by the Abbasid dynasty, which ruled from Baghdad (now the capital of Iraq).

In the mid-800's, the Abbasids began to lose control over their territories. For most of the period between 868 and 969, two Turkish dynasties—the Tulunid dynasty and the Ikhshidid dynasty—ruled Egypt almost independently of the Abbasid caliphs in Baghdad.

In 969, Fatimid rulers seized Egypt. The Fatimids, who had conquered other lands in northern Africa, made Egypt the center of their expanding empire and broke its ties with the Abbasid state. The Fatimids claimed to be descendants of Fatima, daughter of the Islamic prophet Muhammad. They were members of an Islamic minority group known as Shiites. The Fatimids founded the city of Al-Qahirah (modern-day Cairo), and they made it their capital in 973. They also built al-Azhar mosque, which quickly became the center of Fatimid culture and religion. See **Fatimid dynasty.**

By the mid-1100's, the Fatimid empire was weakened by fighting among various factions and with the Christian Crusaders from Europe (see **Crusades**). In 1168, the Fatimid caliph asked Muslims in Syria to send an army to help defend Egypt from the Crusaders. Saladin, an officer in that army, helped drive the Crusaders out of Egypt. Then in 1171, he overthrew the Fatimid ruler, restored the Sunni form of Islam—that is, the form most Muslims follow—and created an independent state. He became the *sultan* (prince) of Egypt. Saladin was a generous and just ruler. He and his descendants formed the Ayyubid dynasty, which ruled Egypt until 1250.

A group known as the Mamelukes served as the sultan's bodyguard. They were Turkish, Mongol, and Circassian slaves who were given special military training and rose to high positions in the army and government. In 1250, the Mamelukes revolted against the Ayyubid sultan and seized control of Egypt. The Mameluke general Baybars, who later became sultan, saved Egypt from ruin when his forces defeated invading Mongol troops at the battle of Ayn Jalud in Palestine in 1260.

For more than 200 years, rival Mameluke groups competed for authority, with the largest, best-organized, and most ruthless group taking power. But Egypt achieved more in art, architecture, and literature under the Mameluke rulers than at any time since the beginning of the Islamic period. See **Mamelukes.**

Ottoman and French control. The Mameluke empire was declining by 1517. That year, Ottoman forces under Sultan Selim invaded Egypt from Syria and overthrew the Mamelukes. But the Ottomans could not eliminate Mameluke influence. Mamelukes became *beys* (governors) of the regions of Egypt and held the real governing power. By the mid-1700's, Egypt's government was in disarray as Ottoman and Mameluke leaders competed for power. At the same time, the economy suffered from European control of Indian Ocean trade routes that bypassed Egypt.

In 1798, Napoleon Bonaparte led French forces into Egypt. They defeated the Mamelukes in the Battle of the Pyramids (see **Napoleon I** [Egypt invaded]). Napoleon hoped to disrupt the trade routes of Britain (now the United Kingdom), France's chief enemy. He also wanted

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The Ottomans defeated the Mamelukes in a battle near Cairo in 1517. Egypt then became a part of the Ottoman Empire.

to establish a French colony in Egypt. Napoleon brought many French scholars with him to Egypt. Their scientific investigations helped revive the study of Egyptian relics, and their writings provided thorough descriptions of the country at the end of the 1700's.

Napoleon returned to France in 1799, leaving his troops behind. But military defeat, Egyptian resistance, and disease weakened them. The Ottomans, with British assistance, forced the French to withdraw in 1801.

Muhammad Ali and modernization. Muhammad Ali was an officer in the Ottoman army that helped drive the French out of Egypt in 1801. In the disorder following the departure of the French, he gained power rapidly. By 1805, Muhammad Ali had established himself as Egypt's ruler. His killing of Mameluke rivals in 1811 made his rule secure from rebellion. From then on, he carried out a program of modernization.

Muhammad Ali was an energetic leader who ruled with absolute power. Many of his reforms came from a desire to strengthen Egypt's army. Muhammad Ali knew that his position in Egypt remained secure only as long as his army was more powerful than that of the Ottoman sultan. To achieve this goal, he brought in French military experts and patterned his army on that of France. In addition, Muhammad Ali introduced Western education into Egypt. He sent educational missions to Europe and brought European teachers to Egypt. Muhammad Ali also worked to improve agriculture. He began the transformation from basin irrigation to year-round irrigation. He also promoted the industrialization of Egypt.

Many of Muhammad Ali's reforms failed, partly because he tried to do too much too fast. His projects overtaxed the country's resources and caused hardship to much of the population. He also aroused the hostility of the United Kingdom by invading Syria and threatening the existence of the Ottoman Empire, thus upsetting the balance of power in the Middle East. In 1841, the British forced Muhammad Ali to accept a decree that limited his army to 18,000 men. At the time of his death in 1849, Muhammad Ali's industries had collapsed, his educational missions had been disbanded, and many schools had been closed. See **Muhammad Ali.**

Muhammad Ali's immediate successors did not provide strong leadership. His son Said, also called Said Pasha, ruled from 1854 to 1863. Said granted a French company a contract to build a canal through the Isthmus of Suez. The canal was designed to shorten the sailing route between Europe and eastern Asia by linking the Red Sea and the Mediterranean Sea. Construction of the Suez Canal began in 1859, and the canal opened in 1869.

Ismail, Said's nephew, ruled Egypt from 1863 to 1879 and became the *khedive* (ruler). Ismail successfully expanded the educational system; built many roads, canals, and railroads; and increased the export of cotton. But he spent large amounts of money on palaces, boulevards, and public displays. By the 1870's, Ismail's lavish spending had created a large national debt. To help pay off the debt, Ismail sold Egypt's shares of ownership in the increasingly profitable Suez Canal Company to the British government in 1875. As a result, the United Kingdom became the largest shareholder in the canal. See **Suez Canal.**

British control. During the 1800's, the United Kingdom's interests in Egypt steadily increased. When Ismail tried to combat European influence in Egypt, the British helped bring about his removal in favor of his son Tawfiq. In 1881 and 1882, Egyptian army officers led by Colonel Ahmad Urabi staged uprisings in an attempt to establish a more independent and nationalist regime in Egypt. Fears that Urabi's actions would endanger foreign interests eventually led the British to invade Egypt. In

Important dates in Egypt

(For events before A.D. 639, see **Egypt, Ancient.**)

A.D. 639-642 Muslim Arab armies conquered Egypt.
969-1171 The Fatimid dynasty ruled Egypt.
1171-1250 Egypt was governed by the Ayyubid dynasty.
1250-1517 The Mamelukes ruled Egypt.
1517 The Ottoman Empire invaded and occupied Egypt.
1798 Napoleon conquered Egypt.
1801 British and Ottoman troops drove the French out of Egypt.
1869 The Suez Canal was completed.
1875 Egypt sold its share of the Suez Canal to the United Kingdom.
1882 British troops occupied Egypt.
1914 The United Kingdom made Egypt a protectorate.
1922 The United Kingdom gave Egypt nominal independence.
1940-1942 British forces fought Italian and German troops in Egypt during World War II.
1948-1949 The United Nations (UN) sought to divide Palestine into separate Jewish and Arab states. Egypt and other Arab countries went to war against the new Jewish state of Israel, but the Arab armies were defeated.
1952 Army officers forced King Faruk from power.
1953 Egypt became a republic.
1954 Gamal Abdel Nasser came to power in Egypt.
1956 The Egyptian government nationalized the Suez Canal. Israel, France, and the United Kingdom invaded Egypt, but the UN ended the fighting.
1958 Egypt and Syria formed the United Arab Republic. Syria withdrew from the union in 1961.
1960 Construction began on the Aswan High Dam. The dam began operation in 1968.
1967 Israel attacked Egypt, Syria, and Jordan. Egypt lost the Sinai Peninsula to Israel.
1970 Nasser died. Anwar el-Sadat succeeded him as president.
1973 Egypt and Syria attacked Israel and started another Arab-Israeli war.
1978 Egypt and Israel reached a major agreement designed to end the disputes between the two countries.
1981 Sadat was assassinated, and Hosni Mubarak succeeded him as president.
1991 Egypt participated in a military coalition that defeated Iraq in the Persian Gulf War.

September 1882, British forces defeated the Egyptian army at the battle of Tel al-Kabir and marched into Cairo. The British exiled Urabi and returned Tawfiq to power.

During the late 1800's and early 1900's, the khedive ruled Egypt in name only. A series of powerful British administrators actually directed the country's affairs. They improved some aspects of life in Egypt. They put Egypt's finances in order, constructed a series of dams to modernize its irrigation system, and provided efficient government. But educated Egyptians criticized the British for neglecting such social concerns as education and public health. Egyptian nationalism began to emerge, and some people called for independence.

World War I (1914-1918) had a powerful impact on Egypt's relationship with the United Kingdom. Egypt was still actually a part of the Ottoman Empire when the war began. After the Ottomans allied with Germany, the British declared Egypt a *British protectorate* (territory under partial British control). The United Kingdom wanted to protect its interests in Egypt and the Suez Canal. British and Indian troops defended the canal, and British warships prevented enemy ships from using it. Egypt became an important base of Allied operations against Ottoman territory and an important source of labor and supplies. This involvement of Egypt in the war led to outpourings of anti-British sentiment.

Independence. From 1919 to 1922, Egypt was in political turmoil. Nationalists led by Saad Zaghlul renewed demands for independence. When the British arrested and exiled Zaghlul, discontent against the British turned into revolt. For a few months in 1919, the government broke down. Negotiations produced few results.

Finally in 1922, the United Kingdom granted Egypt its independence. But the British kept many powers, including the right to station troops in Egypt. A new constitution took effect in 1923 that established Egypt as a constitutional monarchy. However, Egypt made little progress toward ridding the country of British forces or improving living standards and economic growth. The monarch struggled with the British and with various political parties for supremacy.

In 1936, Egypt and the United Kingdom agreed to a treaty that reaffirmed Egypt's independence. This treaty reduced the number of British troops stationed in Egypt and restricted them to the Suez Canal region.

The 1940's. During World War II (1939-1945), Italian and German armies invaded Egypt in efforts to capture the Suez Canal. In 1942, the Allies halted the German advance into Egypt in the Battle of El Alamein. Many Egyptians blamed the British for the violence and hunger in Egypt during the war. For more information on Egypt's involvement in World War II, see **World War II** (Fighting in Africa; In northern Africa).

Egypt became a founding member of the United Nations (UN) in 1945. That same year, Egypt and other Arab nations established the Arab League (see **Arab League**).

After World War II, Egypt's parliamentary parties tried unsuccessfully to dislodge British forces from Egypt. They also had little success in dealing with such problems as poverty, illiteracy, and disease.

In 1947, the UN voted to divide Palestine into Jewish and Arab states. Israel was established in Palestine in 1948. Egypt and other Arab countries immediately went to war against Israel and were defeated. Egyptians, including army officers, blamed the government for the defeat, and support for such groups as the Muslim Brotherhood increased. The Muslim Brotherhood wanted to establish a strictly Islamic government in Egypt and to reclaim all of Palestine for the Arabs.

Republic. In July 1952, a discontented army group known as the Free Officers seized power and sent the reigning monarch, King Faruk, into exile (see **Faruk I**). Gamal Abdel Nasser led the revolt. Nasser believed that Egypt's government was corrupt and that only a change in government could bring economic progress and complete political independence to Egypt.

The Free Officers organized in a body called the Revolutionary Command Council (RCC). The RCC officially took charge of Egypt in September 1952. The army's popular commander in chief, Muhammad Naguib, became prime minister. The council banned all political parties that had participated in elections before 1952, including the Muslim Brotherhood. In June 1953, Egypt was declared a republic, with Naguib serving as both president and prime minister.

During the first two years of military rule, Naguib shared power with Nasser, the deputy prime minister. But Naguib and Nasser could not agree on policies. In April 1954, Nasser became prime minister. In October, the United Kingdom agreed to remove all its troops from Egypt by June 18, 1956. In November 1954, Naguib lost the presidency, and Nasser established unchallenged authority over Egypt. See **Nasser, Gamal Abdel.**

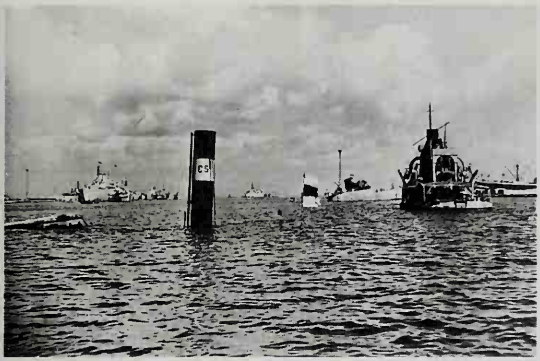
Nasser promoted economic progress in many ways. He increased government spending on education and took over all foreign-run schools. To encourage poor Egyptians to get an education, he provided government jobs for all university graduates. He also wanted to construct a huge new dam on the Nile River to increase the supply of water for irrigation and to provide hydroelectric power (see **Aswan High Dam**).

Nasser sought financing from other countries for the Aswan High Dam project. The United States and the United Kingdom expressed support for the project, but later, in July 1956, withdrew their offers of financial assistance. In retaliation, the Egyptian government seized control of the Suez Canal Company from its British and French owners later that month. Nasser announced that tolls from the canal would provide money for the Aswan High Dam project.

In the meantime, Egypt's relations with Israel worsened. During the 1950's, Egypt supported Palestinian Arabs who raided Israel from the Gaza Strip, the Egyptian-administered part of Palestine. To retaliate, Israel raided the Gaza Strip. Egypt blocked Israeli ships from the Suez Canal and the Gulf of Aqaba.

In October 1956, Israel, in cooperation with the United Kingdom and France, invaded Egypt. Israel occupied the Sinai Peninsula, and the United Kingdom and France captured Port Said. But the United States and the Soviet Union condemned the invasion and brought pressure to bear on the United Kingdom, France, and Israel. The invading troops withdrew, and the Suez Canal Company eventually was compensated for the loss of its property. A UN peacekeeping force was sent to patrol the Egyptian-Israeli border.

The United Arab Republic. Nasser emerged from the Suez incident as a powerful leader of both Egypt and



AP/Wide World

During the Suez fighting in 1956, Egyptians sank their own ships in the Suez Canal to block British and French warships.

the Arab world. He strongly believed in the importance of unity among the Arab countries. In 1958, a group of Syrian leaders asked Nasser to form a political union between Egypt and Syria. Nasser agreed. The two countries became the United Arab Republic (U.A.R.), and Nasser was elected president of the new nation. Syria eventually grew unhappy with Nasser's economic policies and his increasing power, and so it withdrew from the U.A.R. in 1961. But Nasser kept United Arab Republic as Egypt's official name.

In 1962, Egypt intervened in a bitter civil war in Yemen (Sanaa), now part of the country of Yemen. Egyptian soldiers could not end the conflict, but they remained in Yemen (Sanaa) until 1967.

Progress and conflict. The 1960's marked a period of economic and social change in Egypt. By 1962, Nasser's government had taken over almost all of Egypt's large-scale industries, banks, and businesses. Industry, especially textiles and food processing, expanded. Nasser turned to the Soviet Union for help in building the Aswan High Dam. Construction began in 1960, and the dam began operating in 1968. The dam improved and expanded Egypt's irrigation system and enabled Egypt to greatly increase its agricultural production.

Nasser took steps to narrow the gap between rich and poor Egyptians through land reform programs and expansion of the educational system. A law passed in 1952 made it illegal to own more than 200 *feddans* of land. (A feddan equals 1.038 acres, or 0.4201 hectare.) The government distributed any additional land to the *fellahin* (peasants). Land reform acts in the 1960's eventually limited land ownership to 50 feddans by any single landowner or to 100 feddans by a family. At the same time, the government built more schools in an attempt to improve educational opportunities. Many poor Egyptians were able to receive an education and eventually rise to professional and bureaucratic positions.

On June 5, 1967, regional tensions erupted again in an Arab-Israeli war. This six-day conflict was brief but decisive. In the war, Israel almost completely destroyed the air forces of Egypt and other Arab countries. The Israeli army then invaded the Sinai Peninsula and positioned itself on the eastern bank of the Suez Canal. When the fighting ended on June 10, Israel also occupied the Gaza Strip, the West Bank of the Jordan River, and the Golan Heights of Syria. The UN arranged a cease-fire.

The war was a territorial and military disaster for the Arab countries. Nasser had overestimated Egypt's military preparedness. The swift Israeli assaults took the Egyptian forces by surprise.

After the 1967 war, Nasser resigned. But the Egyptian people refused to accept his resignation. Nasser remained president until his sudden death in 1970.

Renewed warfare and peace. Vice President Anwar el-Sadat won the struggle for power that followed Nasser's death. He changed Egypt's official name to the Arab Republic of Egypt in 1971.

Sadat proved to be a shrewd politician. He worked toward two goals: (1) the restoration of lands lost to Israel, and (2) economic growth. To achieve these goals, he believed that the support of the United States was vital. Thus, Sadat broke the ties with the Soviet Union that Nasser had maintained.

In October 1973, along with Syria, Sadat launched a bold and unexpected military assault across the Suez Canal against the Israelis in the Sinai Peninsula. His early success helped win support from other Arab countries. But the Israeli army, resupplied by the United States, eventually drove Egyptian forces back across the Suez Canal. Nevertheless, Sadat drew U.S. attention to the importance of stability in the Middle East and emerged as a powerful world leader. Egypt and Israel agreed to a separation of their forces in the Sinai in 1974. In 1975, they reached an agreement in which Israel removed its troops from a part of the Sinai that it had occupied since 1967. The Suez Canal, which had been closed as a result of the 1967 war, reopened in June 1975.

Sadat sought to regain the entire Sinai Peninsula and to end the state of war readiness that existed between Egypt and Israel. In 1977, he made a historic trip to Israel and addressed the Israeli Knesset (parliament). The following year, Sadat and Israeli Prime Minister Menachem Begin met in the United States for discussions with U.S. President Jimmy Carter. The discussions resulted in a major agreement called the Camp David Accords. It was the first such agreement between Israel and an Arab state. The agreement guaranteed the return of the Sinai Peninsula to Egypt, and called for the creation of a peace treaty between Egypt and Israel. The treaty was signed in 1979.

At home, Sadat worked to revitalize the private sector of the economy. His economic policy, called *infitah* (opening), was designed to allow foreign investment in Egypt and greater private participation in the economy. Sadat hoped to improve relations with the United States and bring about economic growth.

Despite Sadat's vision, his policies did not meet with great success. Other Arab states rejected his treaty with Israel and criticized Sadat for negotiating independently of them. They removed Egypt from the Arab League in 1979. Many Egyptians felt Sadat had given up too much to Israel to regain the Sinai Peninsula. In addition, prosperity did not follow the signing of the Accords, as many had hoped. Discontent grew, led by radical Islamic groups. A group of extremists assassinated Sadat in October 1981 as he watched a parade.

Recent developments. Vice President Hosni Mubarak succeeded Sadat as president. He reaffirmed Sadat's peace treaty with Israel, sustained ties with the United States, and encouraged the private sector of the econo-

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The Camp David Accords were signed in 1978 by, *left to right,* Egyptian President Anwar el-Sadat, United States President Jimmy Carter, and Israeli Prime Minister Menachem Begin.

my. But Mubarak was much less outspoken on many controversial issues and worked to repair Egypt's ties with other Arab nations. Egypt was readmitted to the Arab League in 1989.

Egypt's strategic importance enabled it to gain economic and military aid from the United States and the Soviet Union. But these alliances did not benefit the people greatly. Egypt's problems remain much the same as throughout the 1900's. The population is too large for Egypt's resources and continues to grow rapidly.

In 1990, Iraq invaded Kuwait. Egypt took a leading role in Arab opposition to the invasion. In early 1991, war broke out between Iraq and a coalition that was formed by the United States, Egypt, and other nations. Egyptian troops participated in the efforts to liberate Kuwait (see **Persian Gulf War**).

In October 1992, an earthquake struck Cairo and neighboring suburbs. The disaster caused more than 560 deaths and about $1 billion in property damages.

In the early 1990's, violence by radical Islamic organizations, particularly the Islamic Group, increased. These groups attacked Egyptian Christians and foreigners, especially foreign tourists. In a crackdown on the violence, Egyptian authorities raided extremist strongholds. They made mass arrests and imprisoned thousands of suspects. A number were executed. The Egyptian government also used the state-controlled media to discredit armed Islamic groups. As a result, extremist violence became less of a threat by the end of the 1990's. However, restrictive emergency regulations have remained in place in Egypt.

In 1997, President Mubarak launched a massive, 20-year development project to irrigate desert land and turn it into farmland. Under this project, water is to be pumped from Lake Nasser through a canal to a region of the Western Desert. The area under development is to be called the New Valley. The government expects the New Valley to provide homes and farms for Egypt's fast-growing population.

Meanwhile, Egypt's government has been selling some of its companies to private owners. The aim of this *privatization* is to attract domestic and foreign investment, help the country's economy, and create jobs.

Michael J. Reimer

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VII. **History**

Questions

Why did Napoleon lead French forces into Egypt?
What is Egypt's largest political party?
Which land region covers about two-thirds of Egypt's total area?
Why did the United Kingdom make Egypt a protectorate in 1914?
Where do almost all of Egypt's people live?
How did the United Kingdom become the largest shareholder in the Suez Canal Company in 1875?
What is Egypt officially called?
How does Islam influence life in Egypt?
How did Sadat draw U.S. attention to the importance of military stability in the Middle East?
What is Egypt's most valuable cash crop?

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WORLD BOOK illustration by Linden Artists Ltd.

The Nile River was the lifeblood of ancient Egypt. Its floodwaters deposited rich, black soil on the land year after year, enabling farmers to grow huge supplies of food. The Nile also provided water for irrigation and served as ancient Egypt's main transportation route.

Ancient Egypt

Egypt, Ancient, was the birthplace of one of the world's first civilizations. This advanced culture arose about 5,000 years ago in the Nile River Valley in northeastern Africa. It thrived for over 2,000 years and so became one of the longest lasting civilizations in history.

The mighty Nile River was the lifeblood of ancient Egypt. Every year, it overflowed and deposited a strip of rich, black soil along each bank. The fertile soil enabled farmers to raise a huge supply of food. The ancient Egyptians called their country *Kemet*, meaning *Black Land*, after the dark soil. The Nile also provided water for irrigation and was Egypt's main transportation route. For all these reasons, the ancient Greek historian Herodotus called Egypt "the gift of the Nile."

The ancient Egyptians made outstanding contributions to the development of civilization. They created the world's first national government, basic forms of arithmetic, and a 365-day calendar. They invented a form of picture writing called *hieroglyphics*. They also invented *papyrus*, a paperlike writing material made from the stems of papyrus plants. The Egyptians developed one of the first religions to emphasize life after death. They built great cities in which many skilled architects, doctors, engineers, painters, and sculptors worked.

Leonard H. Lesko, the contributor of this article, is Chairman of the Department of Egyptology at Brown University.

The best-known achievements of the ancient Egyptians, however, are the pyramids they built as tombs for their rulers. The most famous pyramids stand at Giza. These gigantic stone structures—marvels of architectural and engineering skills—have been preserved by the dry climate for about 4,500 years. They serve as spectacular reminders of the glory of ancient Egypt.

The Egyptian world

The land. Ancient Egypt was a long, narrow country through which the Nile River flowed. Deserts bordered the country on the east, south, and west. The Mediterranean Sea lay to the north. The Nile River flowed north out of central Africa through the Egyptian desert to the Mediterranean. The Egyptians called the desert *Deshret*, meaning *Red Land*. The Nile's course through Egypt was about 600 miles (1,000 kilometers). The river split into several channels north of what is now Cairo, forming the Nile Delta. Rolling desert land lay west of the Nile Valley, and mountains rose to the east.

The Nile River flooded its banks each year. The flooding started in July, when the rainy season began in central Africa. The rains raised the level of the river as the

Ancient Egypt

This map shows ancient Egypt during three periods, known as the Old Kingdom, Middle Kingdom, and New Kingdom.

Nile flowed northward. The floodwaters usually went down in September, leaving a strip of fertile land that averaged about 6 miles (10 kilometers) wide on each side of the river. Farmers then plowed and seeded the rich soil. The Egyptians also depended on the Nile as their chief transportation route. Memphis and Thebes—the main capitals of ancient Egypt—and many other cities developed along the river because of its importance to farming and transportation.

The people. Most people of ancient Egypt lived in the Nile River Valley. Scholars believe the valley had from about 1 million to 4 million people at various times during ancient Egypt's history. The rest of the population lived in the delta and on oases west of the river.

The ancient Egyptians had dark skin and dark hair. They spoke a language that was related both to the Semitic languages of southwestern Asia and to certain languages of northern Africa. The Egyptian language was written in hieroglyphics, a system of picture symbols that stood for ideas and sounds. The Egyptians began to use this system about 3000 B.C. It consisted of over 700 picture symbols. The Egyptians used hieroglyphics to inscribe monuments and temples and to record official texts. For everyday use, they developed simpler hieroglyphic forms called *hieratic* and *demotic.*

Ancient Egypt had three main social classes—upper, middle, and lower. The upper class consisted of the royal family, rich landowners, government officials, high-ranking priests and army officers, and doctors. The middle class was made up chiefly of merchants, manufacturers, and craftworkers. The lower class, the largest class by far, consisted of unskilled laborers. Most of them worked on farms. Prisoners captured in foreign wars became slaves and formed a separate class.

Ancient Egypt's class system was not rigid. People in the lower or middle class could move to a higher position. They improved their status mainly through marriage or success in their jobs. Even slaves had rights. They could own personal items, get married, and inherit land. They could also be given their freedom.

Life of the people

Family life. The father headed the family in ancient Egypt. Upon his death, his oldest son became the head. Women had almost as many rights as men. They could own and inherit property, buy and sell goods, and make a will. A wife could obtain a divorce. Few other ancient civilizations gave women all these rights.

Kings commonly had several wives at the same time. In many cases, a king's chief wife was a member of the royal family, such as his sister or half sister.

Children played with dolls, tops, and stuffed leather balls. They had board games with moves determined by the throw of dice. They also had several kinds of pets, including cats, dogs, monkeys, baboons, and birds.

Education. Only a small percentage of boys and girls went to school in ancient Egypt, and most of them came from upper-class families. These students attended schools for scribes. Scribes made written records for government offices, temples, and other institutions. They also read and wrote letters for the large numbers of Egyptians who could not read and write.

The king's palace, government departments, and temples operated the scribal schools. All the schools pre-

pared the students to become scribes or to follow other careers. The main subjects were reading, literature, geography, mathematics, and writing. The students learned writing by copying literature, letters, and business accounts. They used papyrus, the world's first paperlike material, and wrote with brushes made of reeds whose ends were softened and shaped. The Egyptians made ink by mixing water and *soot*, a black powder formed in the burning of wood or other substances.

Most Egyptian boys followed their fathers' occupations and were taught by their fathers. Some boys thus learned a trade, but the majority became farmers. Many parents placed their sons with master craftsmen, who taught carpentry, pottery making, or other skills. Boys who wanted to become doctors probably went to work with a doctor after finishing their basic schooling. Most girls were trained for the roles of wife and mother. Their mothers taught them cooking, sewing, and other skills.

Ancient Egypt had many libraries. A famous library in Alexandria had over 400,000 papyrus scrolls, which dealt with astronomy, geography, and many other subjects. Alexandria also had an outstanding museum.

Food, clothing, and shelter. Bread was the chief food in the diet of most ancient Egyptians, and beer was the favorite beverage. The bread was made from wheat, and the beer from barley. Many Egyptians also enjoyed a variety of vegetables and fruits, fish, milk, cheese, butter, and meat from ducks and geese. Wealthy Egyptians regularly ate beef, antelope and gazelle meat, and fancy cakes and other baked goods. They drank grape, date, and palm wine. The people ate with their fingers.

The Egyptians generally dressed in white linen garments. Women wore robes or tight dresses with shoulder straps. Men wore skirts or robes. The Egyptians often wore colored, shoulder-length headdresses. Rich Egyptians wore wigs, partly for protection against the sun. Wealthy Egyptians also wore leather sandals. The common people usually went barefoot. Young children rarely wore any clothes.

The ancient Egyptians liked to use cosmetics and wear jewelry. Women wore red lip powder, dyed their hair, and painted their fingernails. They outlined their eyes and colored their eyebrows with gray, black, or green paint. Men also outlined their eyes and often wore as much makeup as women. Both sexes used perfume and wore necklaces, rings, and bracelets. Combs, mirrors, and razors were common grooming aids.

The Egyptians built their houses with bricks of dried mud. They used trunks of palm trees to support the flat roofs. Many city houses were narrow buildings with three or more floors. Most poor Egyptians lived in one-room huts. The typical middle-class Egyptian lived in a one- or two-story house with at least 3 rooms. Many rich Egyptians had houses with as many as 70 rooms. Some of these homes were country estates with orchards, pools, and large gardens. Egyptian houses had small windows placed high in the walls to help keep out the sun. The people spread wet mats on the floors to help cool the air inside their houses. On hot nights, they often slept on the roof, where it was cooler.

Ancient Egyptian furniture included wooden stools, chairs, beds, and chests. People used pottery to store, cook, and serve food. They cooked food in clay ovens or over fires and used charcoal and wood for fuel. Candles and lamps provided lighting. The lamps had flax or cotton wicks and burned oil in jars or hollowed-out stones.

Recreation. The ancient Egyptians enjoyed numerous leisure activities. They fished and swam in the Nile River. Sailing on the Nile was a popular family activity. Adventurous Egyptians hunted crocodiles, lions, hippopotamuses, and wild cattle with bows and arrows or spears. Many Egyptians liked to watch wrestling matches. At home, the Egyptians played *senet*, a board game similar to backgammon.

Religion

Gods and goddesses. The ancient Egyptians believed that various *deities* (gods and goddesses) influenced every aspect of nature and every human activity. They therefore worshiped many deities. The main god was the sun god Re. The Egyptians relied on Re and the goddess Rennutet for good harvests. The most important goddess was Isis. She represented the devoted mother and wife. Her husband and brother, Osiris, ruled over vegetation and the dead. Horus, son of Isis and Osiris, was god of the sky. He was called the lord of heaven and was often pictured with the head of a falcon.

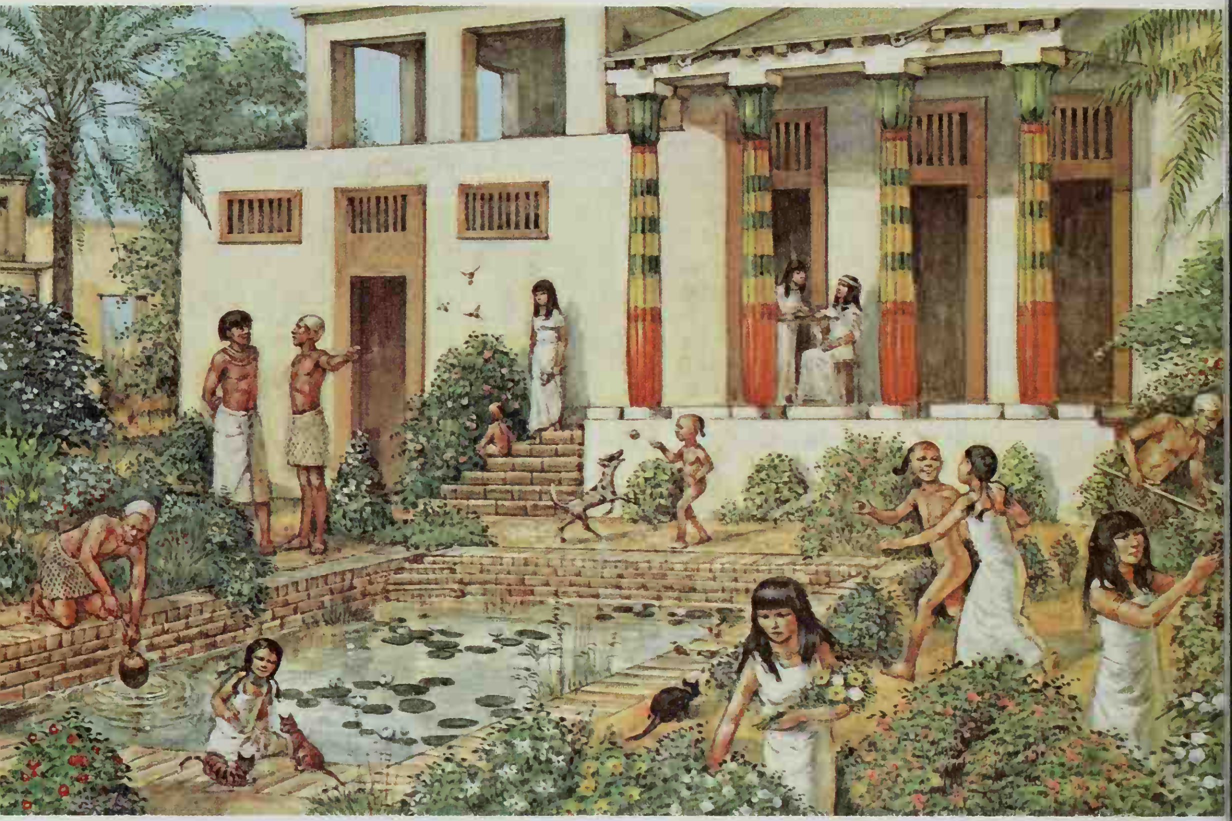
In each Egyptian city and town, the people worshiped their own special god in addition to the major deities. For example, the people of Thebes worshiped Amon, a sun god. Amon was later identified with Re and called Amon-Re. Amon-Re in time became the chief deity. Other local deities and their main centers of worship included Ptah, the creator god of Memphis; Thoth, the god of wisdom and writing in Hermopolis; and Khnum, the creator god of Elephantine. Many deities were pictured with human bodies and the heads of animals. Such a head suggested a real or imagined quality of the animal and made identification of the deity easy.

Most ancient Egyptians prayed at home because the temples did not offer regular services for people. Each temple was either regarded as the home of a certain deity or dedicated to a dead king. A temple built in honor of Amon-Re at Karnak was the country's largest temple. It had more than 130 columns that rose about 80 feet (24 meters). Brilliantly colored paintings decorated the columns and walls in the temple's Great Hall, which still ranks as the largest columned hall ever built.

The priests' main job was to serve the deity or king, who was represented by a statue in the temple. The king reigning at the time was considered the chief priest of Egypt. Each day, he or other local priests washed and dressed the statue and brought it food. Priests also offered prayers requested by individuals.

The afterlife. The ancient Egyptians believed that they could enjoy life after death. This belief in an *afterlife* sometimes led to much preparation for death and burial. It resulted, for example, in the construction of the pyramids and other great tombs for kings and queens. Other Egyptians had smaller tombs.

The Egyptians believed that the bodies of the dead had to be preserved for the next life, and so they *mummified* (embalmed and dried) corpses to prevent them from decaying. After a body was mummified, it was wrapped in layers of linen strips and placed in a coffin. The mummy was then put in a tomb. Some Egyptians mummified pets, including cats and monkeys. A number of Egyptian mummies have survived to the present day.



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A typical country estate in ancient Egypt had a shallow pool enclosed in a courtyard. The pool served as a decoration but also was stocked with fish. Wealthy families had a number of servants and owned at least one dog and several cats. Girls played with dolls and often wore their hair in pigtails. Boys had their heads shaved, except for a braided lock on one side.

The Egyptians filled their tombs with items for use in the afterlife. These items included clothing, wigs, food, cosmetics, and jewelry. The tombs of rich Egyptians also had statues representing servants who would care for them in the next world. Scenes of daily life were painted on walls inside the tombs. The Egyptians believed that certain prayers said by priests would make Osiris bring the scenes as well as the dead to life.

Many Egyptians bought texts containing prayers, hymns, spells, and other information to guide souls through the afterlife, protect them from evil, and provide for their needs. Egyptians had passages from such texts carved or written on walls inside their tombs or had a copy of a text placed in their tombs. Collections of these texts are known as the Book of the Dead.

Work of the people

Most of the workers in the fertile Nile Valley were farm laborers. Great harvests year after year helped make Egypt rich. Many other people made their living in manufacturing, mining, transportation, or trade.

The Egyptians did not have a money system. Instead, they traded goods or services directly for other goods or services. Under this *barter* system, workers were often paid in wheat and barley. They used any extra quantities they got to trade for needed goods.

Agriculture. Most farm laborers worked on the large estates of the royal family, the temples, or other wealthy landowners. They received small amounts of crops as pay, partly because landowners had to turn over a large percentage of all farm production in taxes. Some farmers were able to rent fields from rich landowners.

Ancient Egypt was a hot country in which almost no rain fell. But farmers grew crops most of the year by irrigating their land. They built canals that carried water from the Nile to their fields. Farmers used wooden plows pulled by oxen to prepare the fields for planting.

Wheat and barley were the main crops of ancient Egypt. Other crops included lettuce, beans, onions, figs, dates, grapes, melons, and cucumbers. Parts of the date and grape crops were crushed to make wine. Many farmers grew flax, which was used to make linen. The Egyptians raised dairy and beef cattle, goats, ducks, geese, and donkeys. Some people kept bees for honey.

Manufacturing and mining. Craftsmen who operated small shops made most of the manufactured goods in ancient Egypt. The production of linen clothing and linen textiles ranked among the chief industries. Other important products included pottery, bricks, tools, glass, weapons, furniture, jewelry, and perfume. The Egyptians also made many products from plants, including rope, baskets, mats, and sheets of writing material.

Ancient Egypt had rich supplies of minerals. Miners produced large quantities of limestone, sandstone, and granite for the construction of pyramids and monuments. They also mined copper, gold, and tin and such gems as turquoises and amethysts. Much of Egypt's gold came from the hills east of the Nile.

Trade and transportation. Ancient Egyptian traders sailed to lands bordering the Aegean, Mediterranean, and Red seas. They acquired silver, iron, horses, and cedar logs from Syria, Lebanon, and other areas of southwestern Asia. They got ivory, leopard skins, copper, cattle, and spices from Nubia, a country south of Egypt. For these goods, the Egyptians bartered gold, other minerals, wheat, barley, and papyrus sheets.

Transportation within ancient Egypt was chiefly by boats and barges on the Nile River. The earliest Egyptian boats were made of papyrus reeds. Moved by poles at first, they later were powered by rowers with oars. By about 3200 B.C., the Egyptians had invented sails and begun to rely on the wind for power. About 3000 B.C., they started to use wooden planks to build ships.

During ancient Egypt's early history, most people walked when they traveled by land. Wealthy Egyptians were carried on special chairs. During the 1600's B.C., the Egyptians began to ride in horse-drawn chariots.

Crafts and professions. The royal family and the temples of ancient Egypt employed many skilled architects, engineers, carpenters, artists, and sculptors. They also hired bakers, butchers, teachers, scribes, accountants, musicians, butlers, and shoemakers. The Egyptians' belief that their bodies had to be preserved for the afterlife made embalming a highly skilled profession. Many Egyptians served in the army and navy. Others worked on cargo ships or fishing boats.

Arts and sciences

Architecture. Ancient Egypt's pyramids are the oldest and largest stone structures in the world. The ruins of 35 major pyramids still stand along the Nile. Three huge pyramids at Giza rank as one of the Seven Wonders of the Ancient World, a list of notable things to see that was made up by travelers during ancient times. The first Egyptian pyramids were built about 4,500 years ago. The largest one, the Great Pyramid at Giza, stands about 450 feet (140 meters) high. Its base covers about 13 acres (5 hectares). This pyramid was built with more than 2 million limestone blocks, each weighing an average of $2\frac{1}{2}$ short tons (2.3 metric tons).

The ancient Egyptians also built temples of limestone. They designed parts of the temples to resemble plants. For example, some temples had columns carved to look like palm trees or papyrus reeds. The temples had three main sections—a small shrine, a large hall with many columns, and an open courtyard.

Painting and sculpture. Many of ancient Egypt's finest paintings and other works of art were produced for tombs and temples. Artists covered the walls of tombs with bright, imaginative scenes of daily life and pictorial guides to the afterlife. The tomb paintings were not simply decorations. They reflected the Egyptians' belief that the scenes could come to life in the next world. The tomb owners therefore had themselves pictured not only as young and attractive but also in highly pleasant settings that they wished to enjoy in the afterlife.

Ancient Egyptian sculptors decorated temples with carvings showing festivals, military victories, and other important events. Sculptors also carved large stone sphinxes. These statues were supposed to represent Egyptian kings or gods and were used to guard temples and tombs. The Great Sphinx, for example, is believed to represent either King Khafre or the god Re-Harakhte. This magnificent statue has a human head and the body of a lion. It is 240 feet (73 meters) long and about 66 feet (20 meters) high. The Great Sphinx, which is near the Great Pyramid at Giza, was carved about 4,500 years ago. Sculptors also created small figures from wood, ivory, alabaster, bronze, gold, and turquoise. Favorite subjects for small sculptures included cats, which the Egyptians considered sacred and valued for protecting their grain supplies from mice.

Music and literature. The ancient Egyptians enjoyed music and singing. They used harps, lutes, and other string instruments to accompany their singing. Egyptian love songs were poetic and passionate.

Writers created many stories that featured imaginary characters, settings, or events and were clearly meant to entertain. Other writings included essays on good living called "Instructions."

Sciences. The ancient Egyptians made observations in the fields of astronomy and geography that helped them develop a calendar of 365 days a year. The calendar was based on the annual flooding of the Nile River. The flooding began soon after the star Sirius reappeared on the eastern horizon after months of being out of sight. This reappearance occurred about June 20 each year. The calendar enabled the Egyptians to date much of their history. The dated material from ancient Egypt has helped scholars date events in other parts of the ancient world.

The ancient Egyptians could measure areas, volumes, distances, lengths, and weights. They used geometry to determine farm boundaries. Mathematics was based on a system of counting by tens, but the system had no zeros.

Ancient Egyptian doctors were the first physicians to study the human body scientifically. They studied the structure of the brain and knew that the pulse was in some way connected with the heart. They could set broken bones, care for wounds, and treat many illnesses. Some doctors specialized in a particular field of medicine, such as eye defects or stomach disorders.

Government

Kings ruled ancient Egypt throughout most of its history. Sometime between 1554 and 1304 B.C., the people began to call the king *pharaoh*. The word *pharaoh* comes from words that meant *great house* in Egyptian. The Egyptians believed that each of their kings was the god Horus in human form. This belief helped strengthen the authority of the kings.

The position of king was inherited. It passed to the eldest son of the king's chief wife. Many Egyptian kings had several other wives, called *lesser wives*, at the same time. Some chief wives gave birth to daughters but no sons, and several of those daughters claimed the right to the throne. At least four women became rulers.

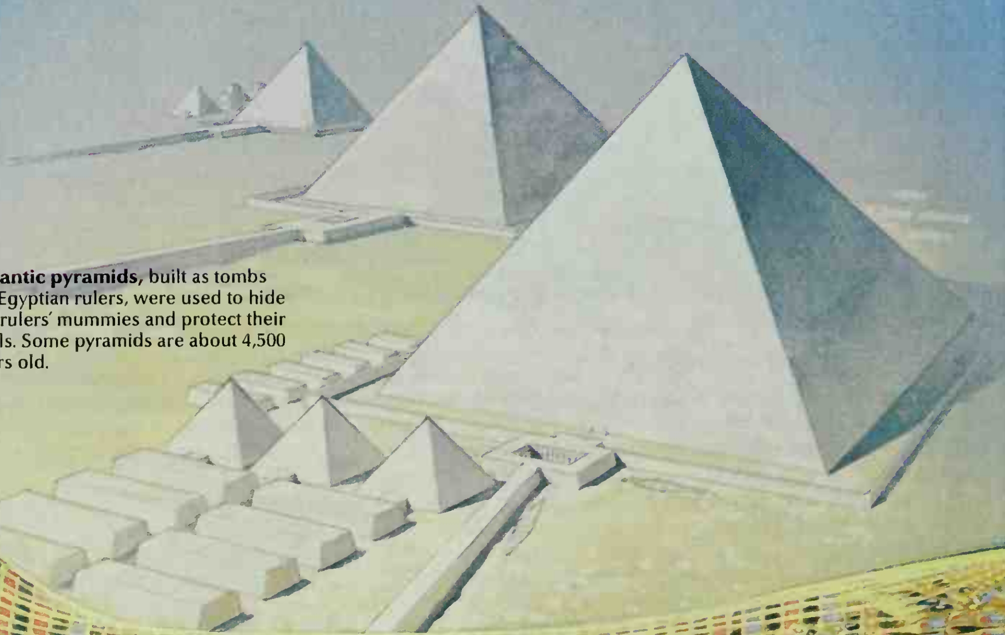
Officials called *viziers* helped the king govern ancient Egypt. By the 1400's B.C., the king appointed two of

Religion of ancient Egypt

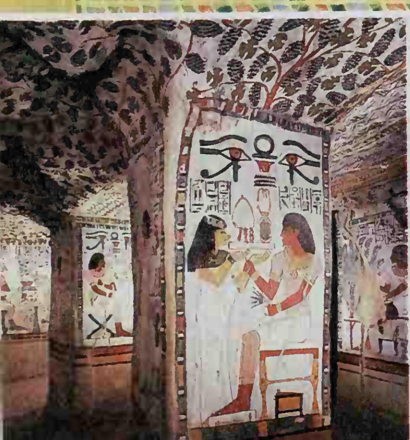
The ancient Egyptians worshiped many *deities* (gods and goddesses) and built huge temples to honor the major ones. The Egyptians also believed they would experience life after death in an *afterlife* and sometimes made elaborate preparations for death and burial. For example, the Egyptians *mummified* (embalmed and dried) corpses to prevent the bodies from decaying and to preserve them for the afterlife. The mummy was then wrapped in linen bandages, placed in a coffin, and put in a tomb.

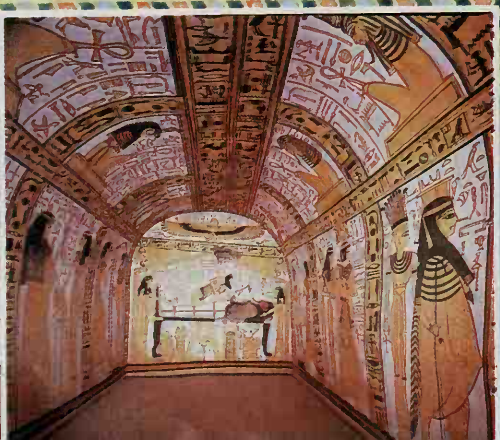
WORLD BOOK illustration by Linden Artists Ltd.

Important deities of ancient Egypt



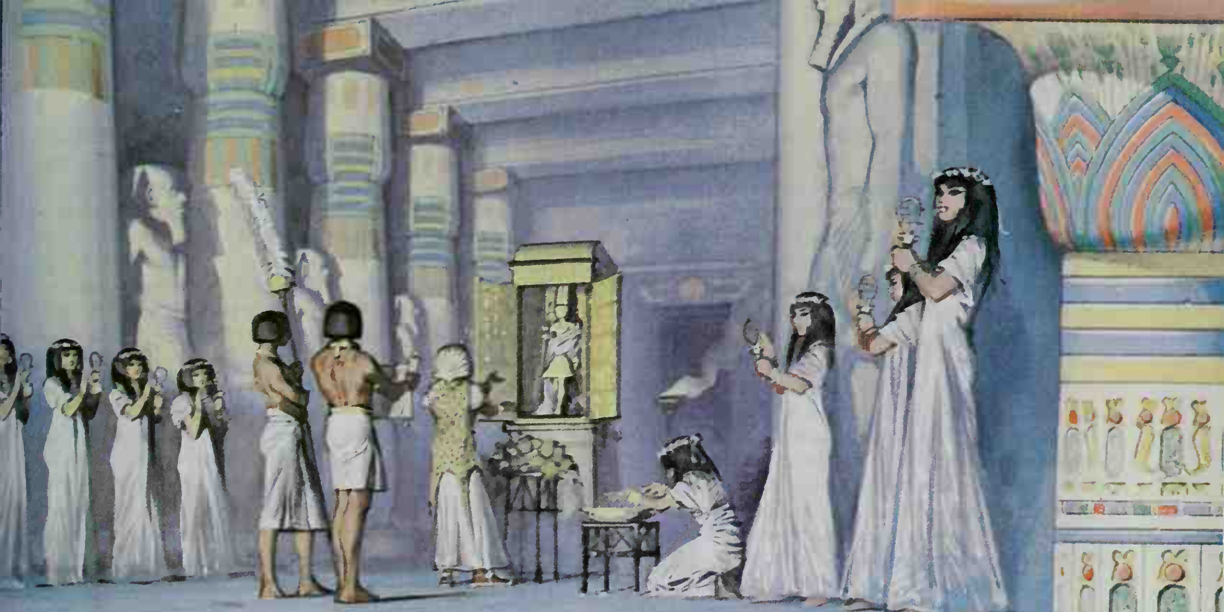
Gigantic pyramids, built as tombs for Egyptian rulers, were used to hide the rulers' mummies and protect their souls. Some pyramids are about 4,500 years old.



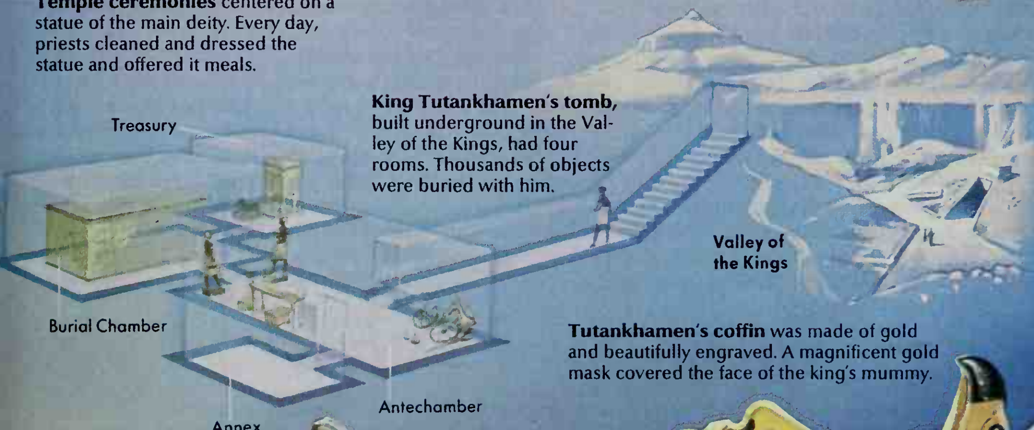


Paintings inside tombs of many ancient Egyptians show the tomb owner as young and attractive in pleasant settings, *left.* The Egyptians believed certain prayers said by priests would make the god Osiris bring the scenes as well as the dead to life in the next world.

© Brian Brake, Photo Researchers



Temple ceremonies centered on a statue of the main deity. Every day, priests cleaned and dressed the statue and offered it meals.



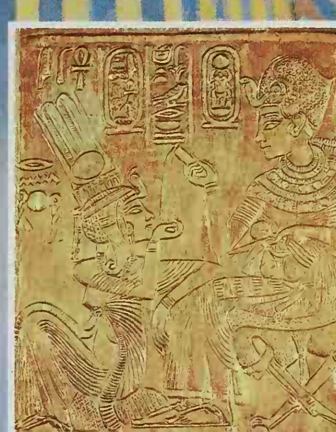
King Tutankhamen's tomb, built underground in the Valley of the Kings, had four rooms. Thousands of objects were buried with him.

Tutankhamen's coffin was made of gold and beautifully engraved. A magnificent gold mask covered the face of the king's mummy.

Treasures from the tomb of Tutankhamen are among the finest examples of ancient Egyptian art. Many objects found in the tomb, such as those at the left and right, show the superb skill of jewelry makers, sculptors, and metalworkers. These items date from the 1300's B.C.

gold pendant

An alabaster cup



A gold-covered shrine

Lee Boltin

them. One vizier administered the Nile Delta area, and the other one managed the region to the south. The viziers acted as mayors, tax collectors, and judges, and some even controlled temple treasuries. Other high officials included a treasurer and army commander. The government collected taxes from farmers in the form of crops. Skilled workers paid taxes in the goods or services they produced. The treasuries of kings and temples were thus actually warehouses consisting largely of crops and various manufactured goods. The government also levied a *corvée* (tax paid in the form of labor) to obtain troops and government workers.

For purposes of local government, ancient Egypt was divided into 42 provinces called *nomes.* The king appointed an official known as a *nomarch* to govern each province. There were courts in each nome and a high court in the capital. Viziers judged most cases. Kings decided cases involving crimes punishable by death.

In its early days, ancient Egypt had a small army of foot soldiers equipped with spears. During the 1500's B.C., Egypt built up a large army. The army included soldiers who were trained to shoot arrows from their bows accurately while riding in fast-moving, horse-drawn chariots. Egypt had a large navy of long ships. These ships were powered chiefly by oarsmen, though most vessels also had sails.

History

Beginnings. The earliest known communities in ancient Egypt were villages established over 5,000 years ago. In time, the villages became part of two kingdoms. One of these kingdoms controlled the villages that lay on the Nile Delta, and the other controlled the villages south of the delta. The delta area was known as Lower Egypt. The southern region was called Upper Egypt.

Egyptian civilization began about 3100 B.C. According to tradition, King Menes of Upper Egypt conquered Lower Egypt at that time. He then united the country and formed the world's first national government. Menes founded Memphis as his capital near the site of present-day Cairo. He also established the first Egyptian *dynasty* (series of rulers in the same family). More than 30 other dynasties ruled ancient Egypt.

The early period of ancient Egyptian history covered Dynasties I and II, which ruled for about 400 years. During this period, the kings built a temple to Ptah, the chief god of Memphis, and erected several palaces near the temple. The Egyptians also developed irrigation systems, invented ox-drawn plows, and began to use hieroglyphic writing during the first two dynasties.

The Old Kingdom. Dynasty III began in 2686 B.C. By that time, Egypt had a strong central government. The next 500 years became known for the construction of Egypt's gigantic pyramids. The period is called the Old Kingdom or the Pyramid Age.

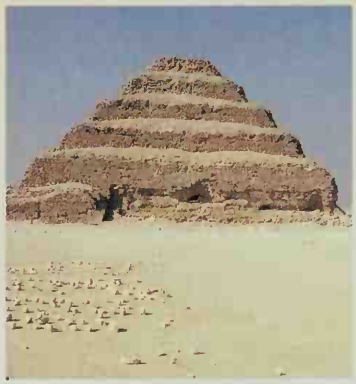
The first known Egyptian pyramid was built for King Zoser at Saqqarah about 2650 B.C. The tomb rises about 200 feet (60 meters) in six giant steps and is called the Step Pyramid. During Dynasty IV, workers built the Great Pyramid and other pyramids at Giza. The Great Pyramid was built for King Khufu. Huge pyramids were built nearby for his son, King Khafre, and for King Menkaure. Farm laborers worked on the pyramids when floodwaters of the Nile covered their fields.

Important dates in ancient Egypt's history

- **c. 3100 B.C.** Egyptian civilization began with the union of Lower and Upper Egypt.
- **c. 2686-2181 B.C.** The Old Kingdom was a period known for the construction of great pyramids.
- **1991 B.C.** King Amenemhet founded Dynasty XII, which greatly increased Egypt's power.
- **c. 1670 B.C.** Hyksos rulers formed a dynasty that ruled Egypt for about 100 years.
- **1490-1436 B.C.** The Egyptian empire reached its height during the reign of King Thutmose III.

Egyptian Museum, Cairo (Giraudon/Art Resource)

King Menes, *center,* was a legendary ruler who united Lower and Upper Egypt and set up the world's first national government.



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The first pyramid in ancient Egypt was built for King Zoser about 2650 B.C. It rises about 200 feet (60 meters) and is called the Step Pyramid.

© John G. Ross, Robert Harding Associates

King Thutmose III led military campaigns into southwestern Asia almost yearly for 20 years and brought Palestine and Syria into the Egyptian empire.

By Dynasty V, the king's authority began to weaken as high priests and government officials fought for power. The Old Kingdom lasted until 2181 B.C., when Dynasty VI ended. Most of the next five dynasties had weak rulers. The capital was finally moved to Thebes.

The Middle Kingdom was the period in ancient Egyptian history during which Dynasty XII ruled. The dynasty was founded in 1991 B.C., when Amenemhet, a vizier in southern Egypt, seized the throne. He moved the capital to Itjawy, near Memphis. Amenemhet and his strong successors, including Senusret I, Senusret III, and Amenemhet III, helped restore Egypt's wealth and power. During Dynasty XII, Egypt conquered Nubia and promoted trade with Palestine and Syria in southwestern Asia. Architecture, literature, and other arts flourished under this dynasty. The Middle Kingdom ended in 1786 B.C.

Weak kings led the next several dynasties. Settlers from Asia gradually spread throughout the Nile Delta, and they seized control of Egypt about 1670 B.C. During the fighting, the immigrants used horse-drawn chariots, improved bows, and other tools of war unknown to the native Egyptians. The immigrants' leaders, called the Hyksos kings, ruled Egypt for about 100 years.

The New Kingdom was a 500-year period in which ancient Egypt became the world's strongest power. The period began in 1554 B.C., with Dynasty XVIII. During this dynasty, native Egyptians drove the Hyksos forces out of Egypt, and Thebes regained its importance. Amon, a god worshiped mainly in Thebes, was increasingly identified with the god Re and called Amon-Re.

At the beginning of Dynasty XVIII, Egypt developed a permanent army that used horse-drawn chariots and other advanced military techniques introduced during the Hyksos period. The dynasty's early rulers led military forces into southwestern Asia. Thutmose I apparently reached the Euphrates River. Queen Hatshepsut, his daughter, also led armies in battle. Egypt developed a great empire and reached the height of its power in the 1400's B.C., under King Thutmose III. He led military campaigns into Asia almost yearly for 20 years and brought the eastern coast of the Mediterranean Sea into the Egyptian empire. Thutmose also reestablished Egyptian control over Kush and surrounding Nubia, which were valuable sources of slaves, copper, gold, ivory, and ebony. As a result of these victories, Egypt became the strongest and wealthiest nation in the Middle East.

The course of Egyptian history changed unexpectedly after Amenhotep IV came to the throne in 1367 B.C. He devoted himself to a sun god called the Aten. The Aten was represented as the disk of the sun. Amenhotep changed his own name to Akhenaten and declared that the Aten had replaced Amon and all other gods except Re. He believed that Re was part of the sunlight that came from the Aten. The king also moved the capital to a new city, Akhetaten, about 175 miles (280 kilometers) north of Thebes. Ruins of the city lie near what is now Tell el Amarna. Akhenaten's religious reforms, which historians call the Amarna Revolution, led to an outpouring of art and sculpture that glorified the Aten. But the changes angered many Egyptians.

Akhenaten's immediate successors ended the unrest. King Tutankhaten removed *-aten* from his name and became Tutankhamen. He restored the old state reli-

Akhenaten became king of Egypt and introduced major religious reforms.

Alexander the Great added Egypt to his empire.

Muslims from Arabia seized Alexandria and completed their conquest of Egypt.

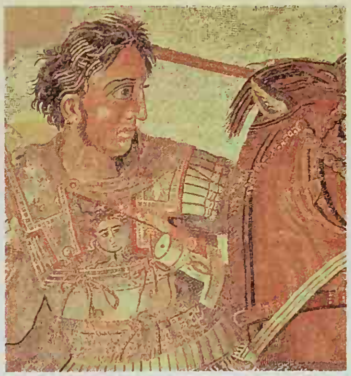
1367 B.C. — c. 1070 B.C. — 332 B.C. — 31 B.C. — A.D. 642

Dynasty XX ended, and Egypt began to decline rapidly as a strong nation.

A Roman fleet crushed an Egyptian force in the Battle of Actium, leading to Rome's take-over of Egypt in 30 B.C.

© Erich Lessing, Magnum

King Akhenaten, *left,* started the Amarna Revolution during the 1300's B.C. He urged the Egyptians to worship a sun god called the Aten.



Detail of a mosaic *Alexander the Great at the Battle of Isso* (150 B.C.); National Archaeological Museum, Naples, Italy (SCALA/Art Resource)

Alexander the Great, king of Macedonia, ended Persia's control of Egypt. Ptolemy, one of Alexander's generals, later founded a dynasty in Egypt.

Portrait on a Roman coin (32 B.C.) (WORLD BOOK photo by James Simek)

Queen Cleopatra VII was the last ruler of Egypt's Ptolemaic dynasty. After she died in 30 B.C., Egypt became a province of Rome.

gion, allowing the worship of the old deities as well as the Aten. Horemheb, the last Dynasty XVIII king, completely rejected Akhenaten's religious beliefs. Dynasty XIX kings erected temples to many gods throughout Egypt. Two of the kings, Seti I and his son, Ramses II, also regained Asian territories lost after the reign of Thutmose III.

Ancient Egypt began to decline during Dynasty XX. Increasingly bitter struggles for royal power by priests and nobles broke the country into small states. Egypt lost its territories abroad, and its weakness attracted a series of invaders.

The periods of foreign control. Ancient Egypt's decline accelerated rapidly after about 1070 B.C., when Dynasty XX ended. During the next 700 years, more than 10 dynasties ruled Egypt. Most of them were formed by Nubian, Assyrian, and Persian rulers. In 332 B.C., the Macedonian conqueror Alexander the Great added Egypt to his empire. In 331 B.C., Alexander founded the city of Alexandria in the delta.

The Ptolemies. Alexander died in 323 B.C., and his generals divided his empire. Ptolemy, one of the generals, gained control of Egypt. About 305 B.C., he took the title of king and founded a dynasty known as the Ptolemies. The dynasty's early rulers spread Greek culture in Egypt. They also built temples to Egyptian gods, developed Egypt's natural resources, and increased foreign trade. Alexandria became Egypt's capital, and its magnificent library and museum helped make the city one of the greatest cultural centers of ancient times.

Roman rule. About 37 B.C., Queen Cleopatra VII of the Ptolemies married Mark Antony, a co-ruler of Rome. Antony wanted to rule the vast Roman lands by himself. He combined his and Cleopatra's military forces to fight forces led by Octavian, another co-ruler of Rome. But the navy of Antony and Cleopatra lost the vital Battle of Actium to Octavian's fleet in 31 B.C. The couple committed suicide the next year, and Octavian then made Egypt a province of Rome. Rome's control of Egypt gradually weakened after A.D. 395, when the Roman Empire split into eastern and western parts. By A.D. 642, Muslims from Arabia had conquered Egypt. For the story of Egypt after 642, see Egypt (History).

Learning about ancient Egypt

The study of ancient Egypt is called *Egyptology,* and experts in the field are *Egyptologists.* Much of their knowledge comes from studying the architecture and other arts of ancient Egypt. Ruins of magnificent temples stand at Abydos, Kom Ombo, Edfu, Esna, Luxor, and Karnak. Excavations of pharaohs' tombs, such as those in a burial ground called the Valley of the Kings, near Luxor, have yielded superb paintings. Tutankhamen's tomb was filled with stunning examples of the ancient Egyptians' skill in woodworking and metalworking.

Information about ancient Egypt also comes from written records made by the Egyptians themselves and by such ancient Greek writers as Herodotus and Strabo. The Egyptians used hieroglyphics until sometime after they came under Roman rule. The ability of anyone to read Egyptian hieroglyphics was then quickly lost.

For over 1,000 years, scholars tried but failed to decipher the writing system of ancient Egypt. Then, in 1799, a rock slab with ancient Greek and Egyptian writing was found outside Rosetta, a city near Alexandria. A French scholar named Jean François Champollion began to compare the Greek and Egyptian words on the so-called Rosetta stone. By 1822, he had deciphered the hieroglyphics. Dictionaries developed since then have helped scholars translate the writings on many monuments and in temples and tombs.

Leonard H. Lesko

Related articles in *World Book* include:

Biographies

Akhenaten	Hatshepsut	Nefertiti	Seti I
Alexander the Great	Hypatia	Ptolemy I	Thutmose III
Cleopatra	Imhotep	Ramses II	Tutankhamen
	Khufu		

Contributions to civilization

Architecture (Egyptian)	Obelisk
Book (Early books)	Painting (Egyptian painting)
Bread (History)	Papyrus
Calendar	Pyramids
Clothing (Ancient times)	Science (picture: Egyptian geometry)
Furniture (Ancient Egypt)	Sculpture (Beginnings)
Geometry (History)	Ship (Egyptian ships)
Glass (History of glass)	Sphinx
Hieroglyphics	Surveying
Mythology (Egyptian mythology)	Textile (History)

Gods and goddesses

Amon	Horus	Osiris	Serapis	Thoth
Anubis	Isis	Re	Seth	

Other related articles

Abu Simbel, Temples of	Asp	Lotus	Rosetta stone
Agriculture (picture)	Cat (History)	Memphis	Scarab
Alexandria	Cleopatra's Needles	Mummy	Thebes (Egypt)
Animal worship	Copts	Nile River	Valley of the Kings
	Hyksos	Nubia	
	Kush	Pharaoh	

Outline

I. **The Egyptian world**
   - A. The land
   - B. The people

II. **Life of the people**
   - A. Family life
   - B. Education
   - C. Food, clothing, and shelter
   - D. Recreation

III. **Religion**
   - A. Gods and goddesses
   - B. The afterlife

IV. **Work of the people**
   - A. Agriculture
   - B. Manufacturing and mining
   - C. Trade and transportation
   - D. Crafts and professions

V. **Arts and sciences**
   - A. Architecture
   - B. Painting and sculpture
   - C. Music and literature
   - D. Sciences

VI. **Government**

VII. **History**

VIII. **Learning about ancient Egypt**

Questions

Why did the ancient Greek historian Herodotus call Egypt "the gift of the Nile"?
What were some achievements of the ancient Egyptians?
Why did the ancient Egyptians make mummies?
What was the Amarna Revolution?
Why did the Egyptians build pyramids?
What discovery led to the deciphering of the ancient Egyptian hieroglyphics in modern times?
When did ancient Egypt reach the height of its power?
What did the ancient Egyptians call their country? Why?
From where does our knowledge of ancient Egypt come?
What was the chief industry in ancient Egypt?

Additional resources

Level I

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Level II

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Reeves, Nicholas. *Ancient Egypt.* Thames & Hudson, 2000.
Shaw, Ian, ed. *The Oxford History of Ancient Egypt.* Oxford, 2000.

Egyptology. See Egypt, Ancient (Learning about ancient Egypt).

Ehrlich, *AYR lihk,* **Paul** (1854-1915), a German bacteriologist, founded chemotherapy and showed that certain dye injections cure certain tropical diseases. He discovered the compound Salvarsan (arsphenamine), a remedy for syphilis, which he described in 1910. Salvarsan is also called "606" because it was the 606th compound that Ehrlich tested.

With Robert Koch, Ehrlich contributed to our knowledge of the tuberculosis germ. Ehrlich founded modern hematology by developing techniques for staining the various types of blood corpuscles. He also worked at increasing immunity to disease, including the development of diphtheria antitoxin.

Ehrlich developed methods of research on cancerous tissues. In addition, he produced strains of cancerous tumors that are still used in experiments with cancer-fighting substances. Ehrlich shared the 1908 Nobel Prize for physiology or medicine for his research on the potency of serum preparations. Ehrlich was born on March 14, 1854, in Strehlen, Silesia, near Wrocław. Audrey B. Davis

Ehrlich, *AYR lihk,* **Paul Ralph** (1932-), an American biologist, is a leader of the international movement for population control. In his book *The Population Bomb* (1968), Ehrlich claimed that the world's population was growing faster than its food supply. He warned that hundreds of millions of people would starve to death as a result of overpopulation.

Many scientists criticized some of Ehrlich's statements as exaggerations. Although he agrees that other factors are involved, Ehrlich continues to stress that overpopulation is the most important cause of hunger and environmental problems.

In 1968, Ehrlich helped form an organization called Zero Population Growth. This group urges every family to have no more than two children. Ehrlich was born on May 29, 1932, in Philadelphia. Sheldon M. Novick

Eichmann, Adolf (1906-1962), was a lieutenant colonel in the Nazi secret police in Germany. He was convicted and executed for his part in the killing of about 6 million Jews during World War II (1939-1945). This state-sponsored campaign of murder became known as the Holocaust.

Eichmann directed the deportation to concentration camps of Jews from Germany and the occupied countries. After the war, he escaped to Argentina and lived there under an assumed name.

Israeli agents seized Eichmann in May 1960 and took him to Israel for trial on charges of crimes against the Jewish people, crimes against humanity, and war crimes. An Israeli court sentenced Eichmann to death in December 1961, after a trial that lasted several months. He was hanged in 1962. Eichmann was born on March 19, 1906, in Solingen, Germany. Donald M. McKale

Eider duck, *EYE duhr,* is the name of four species of ducks known for their soft, warm down feathers. Eider down is a light, highly efficient insulating material and is used to make pillows, bedding, and coats. It grows under the duck's outer feathers and is collected from nests in the early summer. Eider ducks live in northern coastal areas of North America, Europe, and Asia. Adult males have spectacular colors and patterns on the head. Females are dark brown with brown and black streaks.

The *common eider* is the most abundant of the four species. In North America, it is found on coasts from New England north and across the Arctic to Alaska. It can weigh up to 5 $\frac{1}{2}$ pounds (2.5 kilograms). The female typically lays 3 to 4 greenish eggs. Rodger D. Titman

Scientific classification. Eiders belong to the tribe Mergini of the family Anatidae. The scientific name for the common eider is *Somateria mollissima.*

See also Duck (Sea ducks).

Eielson, *EYE uhl suhn,* **Carl Ben** (1897-1929), an American aviator and explorer, piloted the first airplane to cross the Arctic Ocean. Eielson made the flight in April 1928 with the Australian explorer Hubert Wilkins, who organized the expedition. The pair flew 2,200 miles (3,540 kilometers) from Point Barrow, Alaska, to Spitsbergen, an island in the Arctic Ocean. In December 1928, Eielson and Wilkins made the first air explorations of Antarctica. They charted several unknown islands.

Eielson was born on July 20, 1897, in Hatton, North Dakota. He became a pilot in the United States Army Air Service in 1918. Eielson went to Fairbanks, Alaska, to work as a high school teacher. He founded a commercial air service in Fairbanks in 1923 and set up the first airmail route in Alaska in 1924. He died in a plane crash in Siberia while on a rescue mission. Tom D. Crouch

Eiffel, *EYE fuhl,* **Gustave,** *goos TAV* (1832-1923), a French structural engineer, built the 984-foot (300-meter) Eiffel Tower in Paris for a world's fair in 1889. He was a leading bridge designer. His notable bridges include the wrought iron bridge at Porto, Portugal, and the Garabit viaduct in southern France. Eiffel also designed many other iron structures, including the framework for the Statue of Liberty. Eiffel was born on Dec. 15, 1832, in Dijon, France. Terry S. Reynolds

Eiffel Tower, *EYE fuhl,* is the most famous landmark in Paris. It was erected as the symbol of a world's fair called the Universal Exposition of 1889. The tower was the world's tallest structure then, rising 984 feet (300 meters)

©Eric Crichton, Bruce Coleman Ltd

Eiffel Tower

above the fairgrounds. Gustave Eiffel, a structural engineer, built the tower to show how steel and iron could be used to erect tall structures. He was responsible for financing the tower's construction, which cost over $1 million. About 2 million people visited the tower in the first year. The fees they paid covered the building costs.

The Eiffel Tower stands in a park called the Champ de Mars, near the Seine River. The building includes observation decks and restaurants. J. William Rudd

See also **Paris** (picture: The sights of Paris).

Eighteenth Amendment. See **Constitution of the United States** (Amendment 18); **Volstead Act.**

Eikon. See **Icon.**

Eilat. See **Elat.**

Einstein, Albert (1879-1955), was the most important physicist of the 1900's and one of the greatest and most famous scientists of all time. He was a *theoretical physicist,* a scientist who creates and develops theories of matter and energy. Einstein's greatness arose from the fact that his theories solved fundamental problems and presented new ideas. Much of his fame came from the fact that several of those ideas were strange and hard to understand—but proved true.

Some of Einstein's most famous ideas make up parts of his *special theory of relativity* and his *general theory of relativity.* For example, the special theory describes an entity known as *space-time.* This entity is a combination of the dimension of time and the three dimensions of space—length, width, and height. Thus, space-time is four-dimensional. In the general theory, matter and energy *distort* (change the shape of) space-time; the distortion is experienced as gravity.

Einstein also became known for his support of political and social causes. Those included *pacifism,* a general opposition to warfare; *Zionism,* a movement to establish a Jewish homeland in Palestine; and *socialism,* a political system in which the means of production would be owned by society and production would be planned to match the needs of the community.

Early years

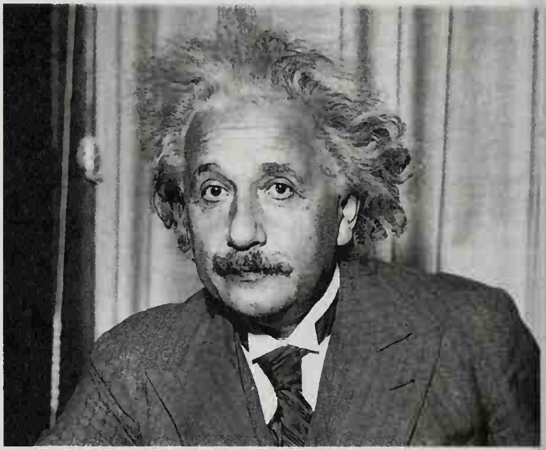
Einstein was born on March 14, 1879, in Ulm, in southern Germany, the son of Hermann Einstein and Pauline Koch Einstein. The next year, Hermann moved the family about 70 miles (110 kilometers) to Munich.

Albert Einstein's younger sister, Maria—whom he called Maja (pronounced *MAH yah*)—recalled that Einstein was slow to learn to speak. But even as a young child, he displayed the powers of concentration for which he became famous.

Einstein recalled seeing the seemingly miraculous behavior of a magnetic compass when he was about 5 years old. The fact that invisible forces acted on the compass needle made a deep impression on the boy.

A booklet on Euclidean geometry made a comparable impression on Einstein when he was about 12 years old. Euclidean geometry is based on a small number of simple, *self-evident* (obviously true) statements about geometric figures. Mathematicians use those statements to *deduce* (develop by reasoning) other statements, many of which are complex and far from self-evident. Einstein was impressed that geometric statements that are not self-evident could be proved clearly and with certainty.

Education. Einstein began to take violin lessons when he was 6 years old. He eventually became an accomplished violinist, and he played the instrument throughout his life.



© Hulton/Archive

Albert Einstein was one of the greatest scientists of all time.

At the age of 9, Einstein entered the Luitpold Gymnasium, a distinguished secondary school in Munich. He enjoyed some of his classes and performed well, but he disliked the strict discipline. As a result, he dropped out at age 15 to follow his parents to Pavia, Italy, near Milan.

Einstein finished high school in 1896, in Aarau, Switzerland. He then entered a school in Zurich, Switzerland, that ranked as one of Europe's finest institutions of higher learning in science. The school is known as the Swiss Federal Institute of Technology Zurich or the ETH Zurich, from the initials for *Federal Institute of Technology* in German. While at the ETH, Einstein met and fell in love with Mileva Maric. Mileva was a physics student from Novi Sad, in what is now Serbia.

Einstein often skipped class, relying on the notes of others. He spent his free time in the library reading the latest books and physics journals. Einstein's behavior annoyed Heinrich F. Weber, the professor who supervised his course work. Although professors customarily helped their students obtain university positions, when Einstein neared graduation, Weber did not help him get a university post. Instead, a friend helped him find a job as a clerk in the Swiss Federal Patent Office in Bern. He became a Swiss citizen in 1901.

First marriage. Meanwhile, Mileva had become pregnant. Albert and Mileva's child, a daughter they named Lieserl, was born in January 1902 at the home of Mileva's parents. In January 1903, Albert and Mileva married. They had two more children, Hans Albert in 1904 and Eduard in 1910. However, Lieserl never joined them in Bern, and her fate remains a mystery.

Famous theories. Einstein worked at the patent office from 1902 to 1909. Those years were among his most productive. His job reviewing patent applications left him with much time for physics. In 1905, he obtained a Ph.D. degree in physics by submitting a *dissertation* (a long, formal paper) to the University of Zurich. He had already completed the necessary classwork at the ETH.

The year 1905 is known as Einstein's *annus mirabilis*—Latin for *year of marvels.* In that year, the German scien-

tific periodical the *Annalen der Physik (Annals of Physics)* published three of his papers that were among the most revolutionary in the history of science.

The photoelectric effect. The first paper, published in March 1905, deals with the *photoelectric effect.* By means of that effect, a beam of light can cause metal atoms to release subatomic particles called *electrons.* In a photoelectric device, these freed electrons flow as electric current, so the device produces a current when light shines on it.

Einstein explained that the photoelectric effect occurs because light comes in "chunks" of energy called *quanta.* The singular of *quanta* is *quantum.* A quantum of light is now known as a *photon.* An atom can absorb a photon. If the photon has enough energy, an electron will leave its atom. Einstein received the 1921 Nobel Prize in physics for his paper on the photoelectric effect.

The principle that light comes in quanta is a part of an area of physics known as *quantum mechanics.* Quantum mechanics is one of the "foundation blocks" of modern physics; Einstein's relativity theories are two others.

Brownian motion. The second paper, published in May 1905, explained *Brownian motion,* an irregular movement of microscopic particles suspended in a liquid or a gas. Such motion was named for Scottish botanist Robert Brown, who first observed it in 1827. Einstein's analysis stimulated research on Brownian motion that yielded the first experimental proof that atoms exist.

The special theory of relativity. The third paper, published in June, presented the special theory of relativity. In that paper, titled "On the Electrodynamics of Moving Bodies," Einstein made a remarkable statement about light. He said that constant motion does not affect the *velocity* (speed in a particular direction) of light.

Albert Einstein Archives from the Hebrew University of Jerusalem, Israel

Einstein and his first wife, Mileva, were photographed with their son Hans Albert Einstein in 1904. Albert and Mileva met in college, where they both studied physics. They divorced in 1919.

Albert Einstein Archives from the Hebrew University of Jerusalem, Israel

Albert Einstein and his younger sister, Maria, were especially close throughout their lives. Albert was 14 years old when this picture was taken with Maria, whom he called Maja.

Imagine, for example, that you are on a railroad car traveling on a straight track at a constant speed of one-third the speed of light. You flash a light from the back of the car to the front of the car. You precisely measure the speed of the light. You find that the speed is 186,282 miles (299,792 kilometers) per second—represented by the letter c in scientific equations. A friend standing on the ground also measures the speed of the light.

You might expect your friend's result to be $c + \frac{1}{3}c$. That would be a "common-sense" result consistent with ordinary experience with the velocities of material objects. For example, a ball thrown forward inside a railroad car would have a velocity—as measured by an observer on the ground—equal to the velocity of the car plus the velocity of the ball as measured in the car. But, strangely, in the case of the light beam, your friend's answer turns out to be the same as yours: c.

The strange fact that the velocity of light is constant has even stranger results. For example, a clock can appear to one observer to be running at a given rate, yet seem to another observer to run at a different rate. Two observers can measure the length of the same rod correctly but obtain different results.

Einstein also said that c is a universal "speed limit." No physical process can spread through space at a velocity higher than c. No material body can reach a velocity of c.

Interchangeability of mass and energy. In a fourth paper, published in September 1905, Einstein discussed a result of the special theory of relativity—that energy

and *mass* are interchangeable.

Mass is a measure of an object's *inertia,* its resistance to a change in its motion. Due to inertia, an object at rest tends to remain at rest. A moving object tends to maintain its velocity. In addition, an object's weight is proportional to its mass; more massive objects weigh more.

Einstein's paper contains an equation that has become famous: $E = mc^2$. The equation says that a body's energy, *E,* equals the body's mass, *m,* times the speed of light, *c, squared* (multiplied by itself). The speed of light is so high that the conversion of a tiny quantity of mass releases a tremendous amount of energy.

The conversion of mass creates energy in the sun and other stars. It also produces the heat energy that is converted to electric energy in nuclear power plants. In addition, mass-to-energy conversion is responsible for the tremendous destructive force of nuclear weapons.

Middle years

Academic appointments. By 1909, Einstein was famous within the physics community. That year, he accepted his first regular academic appointment, as an associate professor of theoretical physics at the University of Zurich. In 1911, he became a professor at the German University in Prague, Austria-Hungary (now Charles University in the Czech Republic). In 1912, he returned to the ETH as a professor.

Einstein moved to Berlin in 1914 to become a member of the Prussian Academy of Sciences, a professor at the University of Berlin, and the director of the Kaiser Wilhelm Institute for Physics, a research center then in the planning stage. He headed the institute until 1933. After World War II (1939-1945), the institute was renamed the Max Planck Institute (MPI) for Physics. Several other MPI's for various branches of physics and for other fields of study were later founded.

Second marriage. Mileva went with Albert to Berlin in March 1914 but returned to Zurich in June. Their marriage had become unhappy; and, in 1919, Albert divorced Mileva and married his cousin Elsa Einstein Löwenthal. Einstein's sons stayed in Zurich with Mileva, and Albert adopted Elsa's daughters, Ilse and Margot.

The general theory of relativity. In 1916, the *Annalen der Physik* published Einstein's paper on the general theory of relativity. This paper soon made Einstein world-famous. He suggested that astronomers could confirm the theory by observing the sun's gravitation bending light rays. During a solar eclipse in 1919, the British astronomer Arthur S. Eddington detected the bending aside of starlight by the sun's gravitational field. His observation supported Einstein's theory.

In his theory, Einstein also showed that gravity affects time—the presence of a strong gravitational field makes clocks run more slowly than normal. In addition, equations in the general theory are the basis of descriptions of *black holes.* A black hole is a region of space whose gravitational force is so strong that nothing can escape from it. It is invisible because it traps even light.

Attacks on Einstein. Einstein's world fame came at a price. Einstein was of Jewish descent, and *anti-Semitism* (prejudice against Jews) was increasing in Germany. The physicist and his theories became targets of anti-Semitic verbal attacks. Following the 1922 murder of German foreign minister Walther Rathenau, a Jew, Einstein temporarily left Germany. He visited Palestine and a number of other Asian countries, Spain, and South America.

World travel. Threats of danger did not prevent Einstein from using his fame to promote causes dear to his heart. He took his first trip to the United States in 1921. The main purpose of the trip was not to lecture on physics but to raise money for a planned Hebrew University of Jerusalem. In July 1923, he traveled to Sweden to accept the Nobel Prize in physics that had been awarded to him in 1921.

Further scientific work. After creating the general theory of relativity, Einstein worked on a *unified field theory* that was to include all electric, magnetic, and gravitational phenomena. Such a theory would provide a single description of the physical universe, rather than separate descriptions for gravitation and other phenomena. Einstein worked on the theory for the rest of his life but never finished it; to this day, no one has developed a fully successful unified field theory.

Through the mid-1920's, Einstein was a major contributor to the development of quantum mechanics. By the late 1920's, however, he had begun to doubt the theory.

One reason for Einstein's doubt was that parts of quantum mechanics did not seem to be *deterministic.* Determinism states that strict laws involving causes and effects govern all events. As an example of apparent nondeterminism in quantum mechanics, consider an atom that absorbs a photon, thus becoming more energetic. At a later moment, the atom reduces its energy level by releasing a photon. But a physicist cannot use quantum mechanics to predict the moment of release.

In 1926, Einstein wrote a famous letter to the German physicist Max Born expressing his doubts about quantum mechanics. Einstein wrote, "The theory produces a good deal but hardly brings us closer to the secret of the Old One [by which Einstein meant God]. I am at all events convinced that *He* does not play dice."

In 1936, Einstein and the German physicists Boris Podolsky and Nathan Rosen published an article, which became known as the "EPR paper," arguing that quantum mechanics is not a complete theory. The EPR paper and a reply from the Danish physicist Neils Bohr became the basis for a scientific debate that continues to this day.

© Hulton Archive

Einstein played the violin in a trio on board ship in the 1930's on his way to the United States. Einstein took his first violin lesson when he was 6 years old, and he played throughout his life.


© Hulton/Archive

Einstein did research at the Institute for Advanced Study in Princeton, New Jersey, from 1933 until his death in 1955. He is shown here reading at nearby Princeton University in 1953.

Later years

Einstein in the United States. In December 1930, Einstein traveled to the United States. His trip was the first of what were meant to be annual visits to lecture at the California Institute of Technology. But in January 1933, during Einstein's third trip, the Nazi Party seized power in Germany. The Nazis had an official policy of anti-Semitism, and so Einstein never set foot in Germany again. He returned to Europe in March 1933, staying in Belgium under the protection of that country's royal family. He then went to England.

In September 1933, Einstein sailed to the United States to work at the Institute for Advanced Study, an independent community of scholars and scientists doing advanced research and study. The institute had recently been established in Princeton, New Jersey, and now consists of schools of Historical Studies, Mathematics, Natural Sciences, and Social Science. Princeton would be Einstein's home for the rest of his life. Einstein became a United States citizen in October 1940.

Letter to President Roosevelt. Einstein undertook one of his most important acts in the summer of 1939, shortly before the outbreak of World War II. At the urging, and with the help, of the Hungarian refugee physicist Leo Szilard, Einstein wrote a letter to President Franklin D. Roosevelt. The letter warned that German scientists might be working on an atomic bomb. The letter led to the establishment of the Manhattan Project, which produced the first atomic bomb in 1945.

Continuing fame. After World War II, Einstein labored tirelessly for international controls on atomic energy. He had a wide circle of professional acquaintances and friends, and he was still a world figure. In 1952, he was offered the presidency of Israel—the modern state of Israel had existed only since 1948—but he declined.

Final days. By the early 1950's, Einstein's immediate family had dwindled. His son Eduard had been confined to a mental institution in Zurich for years, suffering from schizophrenia. Einstein's first and second wives, his stepdaughter Ilse, and his sister Maja, to whom he had been especially close, had died. Einstein's son Hans Albert was a professor of civil engineering at the University of California in Berkeley. Of the people who were emotionally close to Albert Einstein, only his stepdaughter Margot and Helen Dukas, his secretary since 1928, remained with him in Princeton.

Einstein signed his last letter one week before his death. In the letter, to the British philosopher and mathematician Bertrand Russell, Einstein agreed to include his name on a document urging all nations to give up nuclear weapons. Einstein died in Princeton on April 18, 1955. Don Howard

Related articles in *World Book* include:

$E=mc^2$	Nuclear weapon
Gravitation (Einstein's theory of gravitation)	Quantum field theory
Manhattan Project	Quantum mechanics
	Relativity

Additional resources

Bernstein, Jeremy. *Albert Einstein and the Frontiers of Physics.* Oxford, 1996.

Brian, Denis. *Einstein: A Life.* Wiley, 1996.

Clark, Ronald W. *Einstein: The Life and Times.* 1971. Reprint. Avon, 1994.

Fölsing, Albrecht. *Albert Einstein.* Viking Penguin, 1997.

Einsteinium (chemical symbol, Es) is an artificially created radioactive element. Its atomic number is 99, and it has 14 isotopes. The most stable isotope of einsteinium has a mass number of 252 and a half-life of 276 days.

Scientists at the University of California, the Argonne National Laboratory, and the Los Alamos National Laboratory named this element in honor of the famous scientist Albert Einstein. Einsteinium was first discovered in 1952 in the debris from a hydrogen bomb explosion. Scientists collected the debris on filter papers carried by radio-controlled airplanes and from fallout on a nearby coral atoll. This new element formed when a great number of neutrons from the explosion collided with atoms of uranium-238 and were captured by their nuclei. Fermium, element 100, was formed at the same time.

Scientists first produced einsteinium in laboratory experiments in 1954. Today, one isotope of einsteinium, with mass number 253 and a half-life of 20 days, is produced in small amounts in nuclear reactors. Einsteinium compounds have also been prepared. Richard L. Hahn

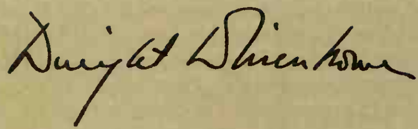
See also **Element, Chemical; Fermium; Transuranium element.**

Einthoven, Willem (1860-1927), a Dutch physiologist, founded electrocardiography. In 1903, he invented the *string galvanometer,* which records variations of electric current. With his galvanometer, he was able to record the minute electrical impulse that travels through the heart with every beat. Modern electrocardiography is the direct outcome of papers published by Einthoven in 1907 and 1908 (see **Electrocardiograph**).

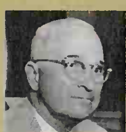
From 1908 to 1913, Einthoven studied the normal electric currents of the heart and so provided the basis for understanding abnormal electric heart currents. Einthoven received the 1924 Nobel Prize in physiology or medicine for his discovery of the way electrocardiography works. He was elected to foreign membership in the British Royal Society in 1926.

Einthoven was born in Semarang, Java. His family moved to the Netherlands in 1870. He studied at the University of Utrecht and became professor of physiology at the University of Leiden at 25. Dale C. Smith

Éire. See **Ireland.**



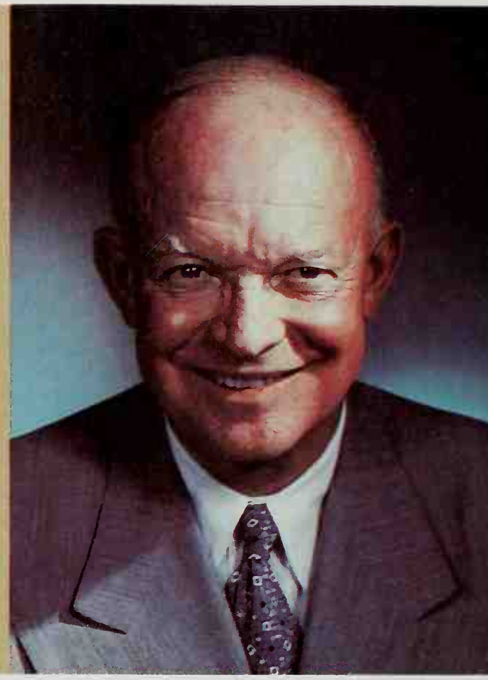
34th President of the United States 1953-1961



Truman
33rd President
1945-1953
Democrat

Eisenhower
34th President
1953-1961
Republican

Kennedy
35th President
1961-1963
Democrat



Karsh, Ottawa

Richard M. Nixon
Vice President
1953-1961

Eisenhower, Dwight David (1890-1969), leader of the victorious Allied forces in Europe in World War II, rode a wave of popularity as a war hero to become President of the United States. Eisenhower had more than 30 years of military experience when he was elected chief executive in 1952, but he was remarkably unmilitary as President. Good leadership, he believed, was not a matter of issuing orders and enforcing obedience. Instead, an effective leader inspired others to cooperate and to use their own talents to the fullest.

Eisenhower was an organized, thoughtful, and patient executive. People throughout the world loved the tall, baldheaded man they fondly called "Ike." His broad grin and friendly manner could put almost anyone at ease.

As President, Eisenhower faced many hard decisions. At home, fear of Communist influence in government led to widespread loyalty investigations. New civil rights issues aroused bitter disputes. In foreign affairs, Communist threats in Asia, Africa, and Latin America caused a series of crises. Eisenhower made little progress in reducing international tensions, yet the soldier in the White House helped keep the world at peace.

Early life

Boyhood. David Dwight Eisenhower—who was always called Dwight David—was born on Oct. 14, 1890, in Denison, Tex. His parents were David Jacob Eisenhower and Ida Stover Eisenhower, a deeply religious couple who belonged to a Protestant sect called the River Brethren. Dwight had two older brothers, Arthur (1886-1958) and Edgar (1889-1971), and three younger ones—Roy (1892-1942), Earl (1898-1968), and Milton (1899-1985). Another brother died as an infant. Dwight's parents were descended from German and Swiss immigrants who had come to Pennsylvania in the 1700's.

When Dwight was still a baby, his family moved to Abilene, Kans. Dwight's father worked in a creamery. The sons raised and sold vegetables and found a variety of other jobs to contribute to household expenses.

Dwight was popular with his classmates, who gave him the nickname "Little Ike" to distinguish him from "Big Ike," his brother Edgar. Both Dwight and Edgar impressed their fellow students. Predictions that appeared in their high school yearbook saw Dwight becoming a history professor and Edgar, interestingly, President of the United States.

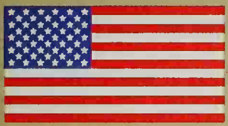
West Point cadet. After high school, Dwight worked full-time at the creamery and helped pay Edgar's first-year college expenses. Dwight had no prospects for his own higher education until a friend persuaded him to apply to the national military academies, where tuition is free. Senator Joseph Bristow of Kansas got Eisenhower an appointment to the U.S. Military Academy at West Point, N.Y. Although Eisenhower chose the career of a soldier, he respected his parents' opposition to war. He considered military service an opportunity for learning and discipline.

Eisenhower played on the football team at West Point. But a knee injury ended his hopes of being a star halfback and forced him to quit the team. In 1915, Eisenhower graduated 61st in a class of 164. The Army assigned the new second lieutenant to Fort Sam Houston, near San Antonio, Tex.

Eisenhower the soldier

Eisenhower's family. While off duty at Fort Sam Houston, Eisenhower coached sports teams. He also met Mamie Geneva Doud (1896-1979), a visitor from Denver, and started to take her to social gatherings at the base. On July 1, 1916, the day of his promotion to

The Space Age began on Oct. 4, 1957. That day, the Soviet Union launched the first artificial satellite, *Sputnik I, above,* into orbit around the earth.



The U.S. flag grew from 48 to 50 stars, *left,* during Eisenhower's presidency. The new stars represented Alaska and Hawaii, which became the 49th and 50th states in 1959.

The world of President Eisenhower

The Korean War ended, after three years of fighting, with the signing of a truce agreement on July 27, 1953.
Controlled nuclear energy came into use. The U.S. Navy launched the first nuclear-powered vessel, the submarine *Nautilus,* in 1954. The first large-scale nuclear power plant began operations in 1956 at Calder Hall in England.
Segregated public schools were outlawed by the Supreme Court of the United States in 1954. In a landmark case, *Brown v. Board of Education of Topeka,* the court ruled that racially segregated schools were unconstitutional.
Rock 'n' roll became the leading form of popular music. A band called Bill Haley and His Comets recorded one of the first rock hits, "Rock Around the Clock," in 1955.
The merger of the American Federation of Labor (AFL) and the Congress of Industrial Organizations (CIO) in 1955 united the two leading U.S. labor federations.
The first polio vaccine, developed by the American medical researcher Jonas E. Salk, was declared safe in 1955.
The Vietnam War began in 1957, when Viet Cong guerrillas started to attack the South Vietnamese government.
The St. Lawrence Seaway, linking the Atlantic Ocean and Great Lakes, was completed by the United States and Canada in 1959.
Fidel Castro took over the government of Cuba in 1959 and soon turned the country into a Communist state.
New inventions included the *laser,* a device that produces a narrow beam of intense light; and *xerography,* an inkless copying process perfected by the Xerox Corporation.

Tass from Sovfoto

first lieutenant, Dwight and Mamie were married.

The young couple's first son, Doud Dwight Eisenhower, died of scarlet fever at the age of 3. The Eisenhowers had a second son, John Sheldon Doud Eisenhower (1922-   ), who became an Army officer and diplomat. In 1968, John's son, David, married Julie Nixon, the younger daughter of Eisenhower's Vice President, Richard M. Nixon.

Early military career. Like most military families, the Eisenhowers continually moved from one Army post to another. Eisenhower directed tank training programs for officers and recruits at Camp Colt, in Gettysburg, Pa., during World War I (1914-1918).

After World War I ended, Eisenhower served on the staff of Brigadier General Fox Conner in the Panama Canal Zone, a strip of land surrounding the Panama Canal then governed by the United States. Conner greatly influenced Eisenhower. The young officer was especially impressed by Conner's self-discipline and attention to detail.

Conner supported Eisenhower's admission to the Army's "leadership factory," the Command and General Staff School at Fort Leavenworth, Kansas. In 1926, Eisenhower graduated first in his class of 275 top Army officers who survived the highly demanding training in tactics and other military skills.

MacArthur's aide. Eisenhower held various posts during the next few years. In 1933, he became an aide to General Douglas MacArthur, the Army chief of staff, in Washington, D.C. In 1935, MacArthur became military adviser to the Commonwealth of the Philippines, a U.S. possession since 1898. He took Eisenhower with him to the Asian country, which was being prepared for independence. Eisenhower planned the military defense of the Philippines and a military academy for the new gov-

Important dates in Eisenhower's life

1890 (Oct. 14) Born in Denison, Tex.
1915 Graduated from West Point.
1916 (July 1) Married Mamie Geneva Doud.
1942 Named commanding general of U.S. forces in the European Theater of Operations.
1943 Named supreme commander of the Allied Expeditionary Force in Europe.
1944 (June 6) Organized the Allied invasion of Europe.
1950 Named supreme commander of NATO forces in Europe.
1952 Elected President of the United States.
1956 Reelected President.
1961 Retired to his farm in Gettysburg, Pa.
1969 (March 28) Died in a hospital in Washington, D.C.

Allen Crenshaw

Eisenhower's birthplace was this two-story white frame house in Denison, Tex. The Eisenhower family moved to Abilene, Kans., when Dwight was nearly 2 years old.

United Press Int.

Eisenhower and his wife, Mamie, were married on July 1, 1916. At the time, Ike was a first lieutenant in the United States Army, stationed at Fort Sam Houston, near San Antonio, Tex.

ernment. He took flying lessons in the Philippines and made a solo flight in 1937, when he was 47 years old.

Rise to prominence. World War II began in 1939. Germany—later joined by Italy, Japan, and other Axis powers—fought the Allies, which included Great Britain, France, and later the Soviet Union and the United States. In 1940, the United States began to build up its military forces in case it was drawn into the war. In 1941, the Army appointed Eisenhower to plan the strategy for the Third Army in war games in Louisiana. The Third Army brilliantly defeated an "enemy" force that included a tank division commanded by Eisenhower's friend George S. Patton, Jr., who also became a World War II hero. Eisenhower's performance earned him a promotion to brigadier general in September 1941. He also caught the attention of General George C. Marshall, who had replaced MacArthur as Army chief of staff.

The United States entered the war in December 1941, after Japan attacked the U.S. naval base at Pearl Harbor, Hawaii. Marshall brought Eisenhower to Washington, D.C., to serve in the Army's war plans division. Eisenhower was promoted to major general in March 1942. In June 1942, he was named commanding general of U.S. forces in the European Theater of Operations. He had been advanced over numerous eligible senior officers.

Eisenhower became a lieutenant general in July 1942. He also was named commander of Allied forces organized to invade North Africa. The invasion began in November 1942 and resulted in the recapture of the region from German and Italian forces. In February 1943, Eisenhower was promoted to the rank of four-star general, then highest in the Army. He organized the Allied invasions of Sicily in July 1943 and of Italy in September 1943. In all these campaigns, he worked to create unity among commanders from different nations. Many of these commanders were stubborn and outspoken, and Eisenhower had to be as much a diplomat as a planner.

Operation Overlord. In 1943, the United States and Great Britain set up a combined staff to plan the Allied invasion of German-occupied Europe. Marshall and Eisenhower were both highly recommended to organize the invasion. But U.S. President Franklin D. Roosevelt did not want Marshall to leave his vital work in Washington. In December 1943, Roosevelt named Eisenhower supreme commander of the Allied Expeditionary Force in Europe.

The Allies planned to cross the English Channel in early June 1944 and to invade Normandy, in northern France. The plan was called Operation Overlord, and it was the largest seaborne invasion in history.

Eisenhower set up headquarters near London and began the enormous responsibility and task of planning the invasion. He had to coordinate the armies and navies of the United States, Great Britain, and the other Allies to ensure that they worked smoothly as one force.

The success of Operation Overlord depended on low tides and calm seas for the landing boats, and clear skies for the bombers protecting them. But on June 3, the weather turned bad, with rough seas and heavy clouds. Weather experts told Eisenhower there was a slim chance that the weather would clear up on June 6. If the invasion did not begin that day, it would have to wait two weeks until the next low tide.

Eisenhower faced the anguish of decision. He could risk millions of lives on the small chance of good weather, or he could delay the landing and probably lose the vital military element of surprise. On June 5, Eisenhower made his final decision. "OK, let's go!" he ordered. The invasion began early in the morning of June 6, 1944, a day that became known as D-Day. By nightfall, the Allies had a firm hold on the beaches of Normandy. After 11 more months of bloody fighting, Germany surrendered on May 7, 1945.

Chief of staff. Eisenhower had received the newly created rank of five-star general in December 1944. A hero's welcome awaited him on his return to the United States in June 1945. He wanted to retire from the military and find a quiet civilian position. However, the nation still needed his services and, in November 1945, he replaced Marshall as Army chief of staff.

Eisenhower argued for a slow disbanding of U.S. armed forces to keep the nation strong. He also wanted to draft all 18-year-old men for one year. But this proposal attracted little support in a nation anxious to return to peacetime life.

Eisenhower also urged that the armed services be unified under a single command. But many military and political leaders opposed such a merger. In 1947, Congress passed a compromise measure unifying the U.S. armed forces under a single secretary of defense.

NATO commander. In 1948, Eisenhower retired from active military service to become president of Columbia University in New York City. He wrote a book about his wartime experiences, *Crusade in Europe* (1948), and was surprised when it became a best seller.


Dwight D. Eisenhower Library

During World War II, General Eisenhower, *right,* served as supreme commander of the Allied forces in Europe. He directed the D-Day invasion of Europe on June 6, 1944.

Eisenhower was soon back in uniform. During the late 1940's, Soviet-controlled Communist governments were established in most countries of Eastern Europe. As a result, the United States and Canada joined several Western European nations in 1949 to form a military alliance called the North Atlantic Treaty Organization (NATO). In 1950, President Harry S. Truman asked Eisenhower to become supreme commander of NATO forces in Europe, which were made up of troops from the member nations. Eisenhower eagerly accepted the job of molding this unique international army.

Road to the White House

Presidential candidate. Eisenhower became involved in politics partly as a result of deep divisions that developed in the United States over the Korean War. The war had begun in June 1950, when troops from Communist North Korea, equipped by the Soviet Union, invaded South Korea. Truman sent American troops to aid South Korea as part of a United Nations (UN) fighting force. Many Republicans supported U.S. participation. But a group of conservative Republicans led by Senator Robert A. Taft of Ohio wanted the United States to withdraw from the war, which had quickly become a bloody stalemate.

Eisenhower disagreed with Taft and the conservatives, known as the Old Guard. Eisenhower did not believe that the United States could live in peace and freedom while refusing to be involved in problems facing the rest of the world. Many Republicans urged Eisenhower to run for President in 1952, arguing that only he could unite the party's conservative and liberal wings and settle issues dividing the nation. Many Democrats also urged him to seek their party's presidential nomination. However, Eisenhower strongly believed in the two-party system and was concerned that there had been no Republican President for the past 20 years.

At first, Eisenhower refused to run for President. He had sent a letter to a New Hampshire newspaper publisher in 1948 calling it "necessary and wise" that professional soldiers "abstain from seeking high political office." He also did not want to become a candidate if it meant opposing Truman, whose defense policies he had helped design.

Truman, however, chose not to run for reelection. In addition, groups called IKE clubs sprang up throughout the country. As a result, Eisenhower decided that a soldier's duty might include service in the White House. He retired from the Army without pay or military benefits and declared himself a candidate for the Republican presidential nomination.

Election of 1952. Taft was the leading candidate for the Republican presidential nomination. At the Republican National Convention in Chicago, however, Lodge and other progressive Republicans helped Eisenhower win the nomination on the first ballot. Nixon, then a young senator from California, became the vice presidential candidate. The Democrats nominated Governor Adlai E. Stevenson of Illinois for President and Senator John J. Sparkman of Alabama for Vice President.

The campaign began slowly. Eisenhower grumbled when reporters talked about his broad grin instead of his experience, "as if I didn't have a brain in my head." His campaign speeches criticized the Truman Administration for "Korea, Communism, and corruption." These themes referred to Truman's conduct of the Korean War and to supposed Communist influence and corruption in the government. Shortly before the election, Eisenhower pledged: "I shall go to Korea" to help end the war.

Eisenhower had several advantages over Stevenson. For example, the new medium of television transmitted Eisenhower's kindliness and dignity far more effectively than Stevenson's intellectual wit. In addition, many Americans blamed the Democratic Party for giving the federal government far too great a role in people's lives. Other Americans believed charges that the Democrats had allowed Communists to gain high government posts. Perhaps most importantly, many people admired Eisenhower's experience and integrity. They believed that he would restore government to its proper role and raise a mighty shield against Communism.

In the election, Eisenhower received almost 34 million popular votes, 55 per cent of the ballots cast. The Republicans also won control of both houses of Congress.

Eisenhower's first Administration (1953-1957)

Eisenhower's methods. As President, Eisenhower delegated wide powers to aides. "This idea that all wis-

Eisenhower's first election

Place of nominating convention	Chicago
Ballot on which nominated	1st
Democratic opponent	Adlai E. Stevenson
Electoral vote*	442 (Eisenhower) to 89 (Stevenson)
Popular vote	33,936,137 (Eisenhower) to 27,314,649 (Stevenson)
Age at inauguration	62

*For vote by states, see **Electoral College** (table).

United Press Int.

In the 1952 presidential election, Eisenhower easily defeated his Democratic opponent, Adlai E. Stevenson. Standing beside him on election night was his wife, Mamie.

Vice President and Cabinet

Vice President	*Richard M. Nixon
Secretary of state	*John Foster Dulles Christian A. Herter (1959)
Secretary of the treasury	George M. Humphrey Robert B. Anderson (1957)
Secretary of defense	Charles E. Wilson Neil H. McElroy (1957) Thomas S. Gates, Jr. (1959)
Attorney general	Herbert Brownell, Jr. William P. Rogers (1957)
Postmaster general	Arthur E. Summerfield
Secretary of the interior	Douglas McKay Frederick A. Seaton (1956)
Secretary of agriculture	Ezra Taft Benson
Secretary of commerce	Sinclair Weeks Lewis L. Strauss (1958) Frederick H. Mueller (1959)
Secretary of labor	Martin P. Durkin James P. Mitchell (1953)
Secretary of health, education, and welfare	*Oveta Culp Hobby Marion B. Folsom (1955) Arthur S. Flemming (1958)

*Has a separate biography in *World Book.*

dom is in the President, in me, that's baloney," he said. Eisenhower made each Cabinet officer and White House assistant responsible for an area of government affairs. He chose officials for their managerial ability and strong convictions.

Shortly after Eisenhower took office, the Department of Health, Education, and Welfare (now the Department of Health and Human Services) was created. Oveta Culp Hobby became the first secretary of the department. Her appointment raised the number of Cabinet members to 10.

"Modern Republicanism" was Eisenhower's term for his legislative program. In domestic affairs, he asked for a reduction in government spending and for better federal management policies. In foreign policy, he emphasized close cooperation with the nation's allies.

In working with Congress, Eisenhower used his personal influence only for a few programs he thought essential. He was often unable to rely on the Republicans in Congress to get legislation passed because they were divided on many issues. He therefore depended on the leadership of the Democratic opposition.

By 1956, the federal government's revenues exceeded its expenses, and a small surplus appeared in the U.S. Treasury. Eisenhower's emphasis on economy also led to a reorganization of the armed forces. The "new look" involved fewer conventional forces but more nuclear weapons. Congress passed several other major fiscal reforms. It gave the nation's tax system a thorough overhaul, broadened the social security system, and increased the minimum wage to $1 an hour.

Despite his desire to cut costs, Eisenhower approved several multibillion-dollar public works programs that he believed would strengthen the economy. One was the St. Lawrence Seaway, a waterway that opened the Great Lakes to ocean ships. It was begun in 1954 and completed in 1959. Another was the interstate highway system, begun in 1956. A proposal to build a dam on the Colorado River drew wide criticism and was rejected.

Challenges from the Old Guard occupied much of the President's attention. One of the most troublesome of these conservative Republicans was Senator Joseph R. McCarthy of Wisconsin, who headed a subcommittee looking for Communists in the government. He had gained national attention in 1950 by charging—with no evidence—that there were Communist spies in the State Department and the Army.

McCarthy also attempted to ban books he considered to be written by Communists. He tried to keep such books out of the State Department libraries in many countries. In a June 1953 speech at Dartmouth College, Eisenhower urged his young audience, "Don't join the book burners." But Eisenhower refused to publicly criticize McCarthy, claiming it was beneath the dignity of the presidency to do so. He explained that he would not "get into the gutter with that guy." As Eisenhower expected, the Senate soon curbed McCarthy. It condemned him in December 1954 for conduct unbecoming a senator. McCarthy's influence quickly declined.

Another Old Guard member challenging the President was Senator John W. Bricker of Ohio. In January 1953, Bricker proposed a constitutional amendment that would require Senate consent for international agreements made by the President. Eisenhower opposed any measure that would reduce the President's power to conduct foreign policy, and his supporters defeated the amendment.

The Republican Party lost control of both houses of Congress in the midterm election of 1954. For the rest of his presidency, Eisenhower had to work with a Democratic-controlled Congress. This situation made it difficult to win support for his programs.

Foreign affairs. Although Secretary of State John Foster Dulles appeared to direct U.S. foreign policy, Eisenhower himself set the course. A month after his election as President, Eisenhower kept his promise to visit Korea. The trip failed to bring immediate results. A truce was finally signed on July 27, 1953.

Working behind the scenes, Eisenhower used the Central Intelligence Agency (CIA) to take action against suspected Communist-sponsored governments. The CIA helped overthrow such governments in Guatemala and Iran during the mid-1950's.

Eisenhower rejected several requests from his advisers that he use nuclear weapons during crises. But the possibility that the United States might use such weapons probably helped bring about the truce in Korea.

The President urged that the world harness nuclear power for peaceful use instead of employing nuclear weapons for war. In a major speech to the UN in December 1953, he suggested that nations contribute nuclear materials to a UN agency that would develop peaceful uses of nuclear energy. His program was called Atoms for Peace. The delegates responded with loud cheers never before heard in the UN. The International Atomic Energy Agency developed from Eisenhower's proposal.

The death of Soviet Premier Joseph Stalin in March 1953 seemed to clear the way for better Soviet-American relations. In July 1955, the leaders of France, Great Britain, the Soviet Union, and the United States attended a so-called *summit meeting* in Geneva, Switzerland. Eisenhower proposed an arrangement called Open Skies, under which the United States and the Soviet Union would allow air inspection of each other's military bases. But the Soviets rejected his proposal.

Illnesses. In September 1955, while on a working vacation in the Rocky Mountains of Colorado, the President suffered a heart attack. He recovered quickly, working from his hospital room by his 65th birthday in October and returning to his desk in December.

United Press Int

Golf, Eisenhower's favorite sport, provided him with relief from the pressures of the presidency. He sometimes played with Vice President Richard M. Nixon, *right.*

The heart attack raised questions about the President's fitness to run for a second term. But Eisenhower could see no one with sufficient experience to succeed him. In February 1956, he announced that he would seek reelection. In June, just as Eisenhower was beginning to campaign, he had an attack of an intestinal disorder called *ileitis* that required surgery. Friends and foes alike wondered whether he could continue to carry the burdens of office.

Election of 1956. The Democrats again chose Stevenson as their candidate for President, with Senator Estes Kefauver of Tennessee as his running mate. A major crisis developed when three traditional U.S. allies—Britain, France, and Israel—carried out a joint air and land attack on Egypt in October 1956. The attack was designed to regain the Suez Canal, which Egyptian President Gamal Abdel Nasser had seized from its British and French owners three months earlier. The canal links the Mediterranean and Red seas and provides access to the oil-rich Middle East.

Eisenhower was shocked that the U.S. allies had secretly decided among themselves to attack. After the attack, the President moved quickly to end the crisis. He immediately ordered the suspension of planned loans to Britain. In the UN, the United States proposed a resolution for a cease-fire. Eisenhower also addressed the United States and the world on television. "There can be no law if we work to invoke one code of international conduct for those who oppose, and another for our friends," he insisted. Britain and France were outraged over what they called Eisenhower's betrayal. However, they withdrew their invasion forces when UN troops arrived to replace those forces.

Eisenhower's handling of the Suez crisis as well as his powers of recovery from illness strengthened the great confidence that American voters had in him. A few days after the speech, the voters went to the polls and awarded Eisenhower an even greater victory than in 1952.

Eisenhower's second Administration (1957-1961)

Life in the White House. The Eisenhowers' eight years in the White House was the longest time they had lived in one place. In 1950, they bought a farm in Gettysburg. It was the first permanent home they owned.

Golf was the President's favorite recreation, and passers-by could sometimes see him practicing golf shots on a special green that was installed on the White House lawn. Eisenhower also liked to cook. Sometimes he invited friends to a cookout on the White House roof, where he broiled steaks on a charcoal grill.

Civil rights. The President favored a deliberate, orderly end to racial discrimination against black Ameri-

Eisenhower's second election

Place of nominating convention	San Francisco
Ballot on which nominated	1st
Democratic opponent	Adlai E. Stevenson
Electoral vote*	457 (Eisenhower) to 73 (Stevenson)
Popular vote	35,585,245 (Eisenhower) to 26,030,172 (Stevenson)
Age at inauguration	66

*For vote by states, see **Electoral College** (table).

Dwight D Eisenhower Library

Premier Nikita S. Khrushchev of the Soviet Union, *second from right,* and his wife, *left,* were guests of the Eisenhowers in 1959. Khrushchev's visit temporarily eased U.S.-Soviet tensions.

Quotations from Eisenhower

The following quotations come from some of Dwight D. Eisenhower's speeches.

Soldiers, sailors and airmen of the Allied Expeditionary Force! You are about to embark upon the Great Crusade . . . I have full confidence in your courage, devotion to duty and skill in battle. We will accept nothing less than full Victory!

Radio broadcast to Allied forces, June 5, 1944, the day before D-Day

. . . in the final choice, a soldier's pack is not so heavy a burden as a prisoner's chains.

First Inaugural Address, Jan. 20, 1953

We know that when censorship goes beyond the observance of common decency . . . it quickly becomes, for us, a deadly danger.

Speech at Columbia University, May 31, 1954

. . . what counts is not necessarily the size of the dog in the fight—it's the size of the fight in the dog.

Speech to the Republican National Committee, Jan. 31, 1958

In the councils of government, we must guard against the acquisition of unwarranted influence, whether sought or unsought, by the military-industrial complex.

Farewell address, Jan. 17, 1961

cans. But in September 1957, a crisis in Little Rock, Arkansas, wrecked his hopes of proceeding slowly in a push for school integration. Governor Orval E. Faubus of Arkansas defied a federal court order to integrate Little Rock Central High School. Faubus used the Arkansas National Guard to prevent black students from entering the school. Eisenhower then placed the National Guard under federal control and sent a regular Army unit, the 101st Airborne Division, to enforce the court order and protect the black students. In a televised address, Eisenhower explained that he had acted in order to prevent further civil disorder.

The space age began on Oct. 4, 1957, when the Soviet Union launched Sputnik 1, the first artificial satellite. On Nov. 3, 1957, the Soviets launched Sputnik 2, a larger satellite that carried a dog as a passenger.

Americans were shocked that the Soviets had beaten the United States in technology, the area of its greatest pride. Many Americans also feared that the Soviet Union might have long-range missiles powerful enough to hit North America. In response, Eisenhower supported two expensive projects that went against his cost-cutting beliefs. One was an all-out effort to quickly catch up to the Soviets in space technology. The other project was to provide federal assistance to schools in support of science education.

The new space program got off to a fast start. On Jan. 31, 1958, the first U.S. satellite, Explorer 1, went into orbit.

Crises in the Middle East and Asia troubled Eisenhower early in his second term. In 1957, he had proposed, and Congress had approved, a policy called the Eisenhower Doctrine. The policy pledged U.S. financial and military aid to any Middle East nation that asked for help against Communist aggression. In July 1958, Eisenhower used the doctrine to send troops to Lebanon to protect its pro-Western government from rebel forces. This involvement helped restore peace and protect United States oil interests in the region. The troops left in October.

In August 1958, China began shelling the Quemoy and Matsu islands, which were held by pro-Western Taiwan. Eisenhower ordered the U.S. Navy to help convoy supplies from Taiwan to the islands. This aid helped end the serious threat to Taiwan.

Midterm elections. In June 1958, congressional investigators revealed that Eisenhower's chief White House aide, Sherman Adams, had received gifts from a Boston businessman who was being investigated by the government. Adams admitted accepting the gifts but denied trying to influence officials in the businessman's favor. Eisenhower stubbornly refused to dismiss Adams. At the urging of Republicans worried about upcoming congressional elections, Adams resigned in September.

A business recession occurred in 1957 and 1958. The unemployment rate rose to 7.3 percent in July 1958. Even though the economy began to recover by the autumn of 1958, the business downturn contributed to a big Democratic victory in the midterm elections of November 1958. The Democrats increased their majority in Congress enough to override presidential vetoes.

U-2 incident. Stalin's successor, Soviet Premier Nikita Khrushchev, agreed to an exchange of visits between himself and Eisenhower and a summit meeting in Paris. Khrushchev came to the United States in September 1959. It was the first visit to the United States by a top Soviet leader.

In May 1960, just before Eisenhower left for the Paris summit, the Soviets shot down an American U-2 spy plane over their territory. In Paris, Khrushchev demanded a U.S. apology. When Eisenhower did not apologize, Khrushchev walked out and withdrew his invitation to Eisenhower to visit the Soviet Union.

Dwight D. Eisenhower Library

Eisenhower's family in 1958 included his four grandchildren—David, Susan, Mary Jean, and Barbara Anne, *seated, left to right.* Standing are his daughter-in-law, Barbara, and son, John.

A break with Cuba occurred near the end of Eisenhower's second term. Fidel Castro, who became dictator of Cuba in 1959, made the country a Communist state. In 1960, he seized all property owned by U.S. companies in Cuba. On Jan. 3, 1961, Eisenhower broke off diplomatic relations with Cuba.

Retirement. Eisenhower was the first president whose term of office was limited by the Constitution. The 22nd Amendment, which became law in 1951, limits a president to two full elected terms. In 1960, the Republicans nominated Vice President Nixon to succeed Eisenhower as president. Nixon lost the election to the Democratic candidate, John F. Kennedy.

Eisenhower left office in January 1961 and retired to his farm at Gettysburg, where he raised cattle and wrote three books of memoirs. After a series of heart attacks, Eisenhower died of heart failure on March 28, 1969. He was buried in Abilene, where a library with his papers opened to researchers soon afterward.

Elmo Richardson

Related articles in *World Book* include:

Adams, Sherman
Cold War
McCarthyism
Nixon, Richard M.
Republican Party (The Eisenhower years)
World War II (D-Day; Victory in Europe)

Outline

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A. Boyhood
B. West Point cadet

II. Eisenhower the soldier
A. Eisenhower's family
B. Early military career
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E. Operation Overlord
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Questions

How did Eisenhower happen to choose an Army career?
What was his Atoms for Peace program?
What were Eisenhower's favorite recreations?
Why was he at first unwilling to run for president?
What was the Eisenhower Doctrine?
How did Eisenhower's decision to begin the D-Day invasion depend on the weather?
Why did Eisenhower break off relations with Cuba?
Could Eisenhower have run for a third term as president of the United States? Why?
Why did Eisenhower send troops to Little Rock, Arkansas?
Who was Eisenhower's vice president?

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Eisenstaedt, *EYE zehn stat,* **Alfred** (1898-1995), an American photographer, is regarded as a pioneer of informal, unposed news photography. He is known chiefly for his *Life* magazine photographs of famous people and

Alfred Eisenstaedt, *Life* Magazine © 1945 Time Inc.

V-J Day—Times Square, a photograph taken by Alfred Eisenstaedt in 1945, captures the jubilation experienced by many Americans on learning that World War II had ended.

world events. Eisenstaedt became one of the first staff photographers for *Life* in 1936. He continued to work for the magazine until 1972. The subjects of some of his memorable photographs include German dictator Adolf Hitler, United States President John F. Kennedy, American actress Marilyn Monroe, Italian dictator Benito Mussolini, and American artist Norman Rockwell.

Eisenstaedt was born on Dec. 6, 1898, in Dirschau, West Prussia (now Tczew, Poland). He first became interested in photography at the age of 14, after his uncle gave him a camera. After serving in the German army, Eisenstaedt took a job selling belts and buttons. He began selling his photographs in 1927. In 1929, he quit his sales job to work full-time as a free-lance photographer. Eisenstaedt came to the United States in 1935 and became a U.S. citizen in 1942. John G. Freeman

Eisenstein, *EYE zuhn STYN,* **Sergei Mikhailovich,** *sehr GAY mih KHY lah vihch* (1898-1948), was a Russian motion-picture director, theorist, and teacher. He became noted for his methods of film editing called *montage* (the arrangement of shots in sequence to suggest a symbolic meaning). For example, in *The Battleship Potemkin* (1925), a shot of an angry ship's crew, combined with soup bubbling in a kettle, implies that the sailors' resentment will soon boil over into mutiny.

Eisenstein's early films, including *Strike* (1925), *Potemkin,* and *October* (also called *Ten Days that Shook the World,* 1928), were semidocumentaries that pioneered in the use of nonprofessional performers. Eisenstein's other films include *The General Line* (1929), *Alexander Nevsky* (1938), and *Ivan the Terrible* (two parts, 1944-1946).

Eisenstein was born on Jan. 23, 1898, in Riga. He entered filmmaking in 1924. Due to political censorship, he completed only six feature films. His film writings have been published as *Film Form, The Film Sense, Notes of a Film Director,* and *Immortal Memories.* Gene D. Phillips

EKG. See **Electrocardiograph.**

El Aaiun, *EHL ah YOON* (pop. 96,784), also called Aiun or Laayoune, is the principal city of Western Sahara, a territory in northwestern Africa. El Aaiun lies about 10 miles (16 kilometers) from the Atlantic Ocean. For the location of the city, see **Africa** (political map). The city and its nearby port are important shipping centers for phosphates, the major mineral product of the area.

The modern city of El Aaiun was founded in 1940 by Spanish military forces. However, a settlement had existed there much earlier. Spain controlled the El Aaiun area from the early 1900's until 1976, when it withdrew and ceded the area to Morocco. But a local Western Saharan group called the Polisario Front opposed Morocco's control (see **Western Sahara** for details). The Moroccan government has worked to develop El Aaiun. It has built new schools and hospitals and replaced many traditional mud-brick buildings with modern houses and apartment buildings. Kenneth J. Perkins

El Alamein, *ehl AH lah MAYN* (pop. 980), is an Egyptian coastal village that lies about 65 miles (105 kilometers) west of Alexandria. For the location of El Alamein, see **Egypt** (political map). El Alamein became famous during World War II. In 1942, German troops led by Field Marshal Erwin Rommel advanced from Tobruk, Libya, as far east as the city in a drive toward Alexandria. Later that year, British troops led by Lieutenant General Bernard L. Montgomery defeated the Germans in two major battles at El Alamein. They prevented the Germans from conquering Egypt and forced them to retreat. This marked a turning point in the war. Today, an Egyptian oil field operates in the desert south of the city. Robert L. Tignor

See also **World War II** (In northern Africa).

Eland, *EE luhnd,* is the largest antelope in Africa. It may stand 6 feet (1.8 meters) tall at the shoulder and weigh 1,500 pounds (680 kilograms). The eland is a calm and graceful animal. It can run as fast as a horse and spring high into the air. All elands have long, spiraled horns and tufted, cattlelike tails. A *dewlap* (fold of skin) hangs from the neck. There are two types of elands. The *common eland* lives in an area from Kenya west to Angola and south to South Africa. The *Derby eland* lives in the area from Sudan to Senegal and Gambia and south to Congo (Brazzaville).

The eland's color varies from deep chestnut or bluish-gray to pale buff or fawn. Most elands have from 8 to 15 vertical white stripes on their sides and a black stripe down their backs. Black patches cover the backs of the forelegs above the knees. In southern Africa, the common eland has faint markings.

Herds of up to 200 elands browse on partly forested land and open plains. During dry seasons, elands can live for weeks without water. C. Richard Taylor

Scientific classification. Elands belong to the family Bovidae. The scientific name for the common eland is *Taurotragus oryx.* The Derby eland is *T. derbianus.*

See also **Antelope** (with picture).

Elasticity is the ability of a solid to return to its original shape and size after it has been deformed by a force. All solids have some elasticity. Familiar materials that have elasticity include the steel in automobile springs and the rubber in basketballs.

Solids return to their original shape and size if the *stress* (deforming force per unit of area) does not exceed a value called the *elastic limit.* If the stress applied to a solid exceeds the solid's elastic limit, the solid will not return to its original shape after the stress has been removed. In the inch-pound system of measurement customarily used in the United States, stress is measured in pounds per square inch. In the metric system, *pascals* are used to measure stress (see **Pascal**).

Stress is related to *strain.* Strain measures how much a given dimension of a solid changes under stress. In many solids, including metals and minerals the stress below the elastic limit is in direct proportion to the strain. The greater the stress, the greater the strain. The ratio of stress to strain, called the *elastic modulus,* is a measure of how well a solid resists deforming forces. A solid with a high elastic modulus, such as steel, has a stronger resistance to stress than a solid with a low elastic modulus, such as rubber. Stanley T. Rolfe

Elat, *EE lat* (pop. 33,300), is an Israeli port on the Gulf of Aqaba, an arm of the Red Sea. It is also spelled *Eilat* (pronounced *ay LAHT*). It serves as Israel's gateway to Asia and East Africa by way of the Indian Ocean. Elat's natural beauty and seaside location make it a popular year-round resort (see **Israel** [map]).

Records indicate that a port existed at Elat's present site during Biblical times. But modern Elat was founded in 1948. Its importance increased after 1950, when Egypt banned Israeli ships from the Suez Canal. Without the

canal, the Gulf of Aqaba became Israel's only outlet to the Red Sea. But Egypt also blocked the entrance to the gulf. The gulf was opened as a result of the Arab-Israeli War of 1956. Elat then grew rapidly in both size and importance. Egypt's blockade of the gulf in 1967 was a major cause of the Six-Day War. See **Israel** (History).

Elat also serves as an import center for oil. A pipeline carries oil from the city to Israel's Mediterranean coast. From there it is either exported or sent to a refinery in Haifa. Bernard Reich

Elba, *EHL buh,* is a mountainous island in the Mediterranean Sea, 6 miles (10 kilometers) southwest of the coast of Tuscany (see **Italy** [terrain map]). Napoleon was exiled to Elba in 1814 (see **Napoleon I** [Exile to Elba]). Elba covers 86 square miles (224 square kilometers) and has a 40-mile (64-kilometer) coastline. It has a population of about 30,000, which increases greatly each summer as tourists arrive to enjoy the beaches and sea breezes. The chief city is Portoferraio. Products include iron, marble, wine, and fruits. Italy governs Elba as part of Livorno province. David I. Kertzer

Elbe River, *EHL buh* or *ehlb,* is one of the major commercial waterways of central Europe. It rises in the western part of the Czech Republic, flows through Germany, and empties into the North Sea. The Elbe is called the Labe in the Czech Republic. It is 724 miles (1,165 kilometers) long (see **Germany** [terrain map]).

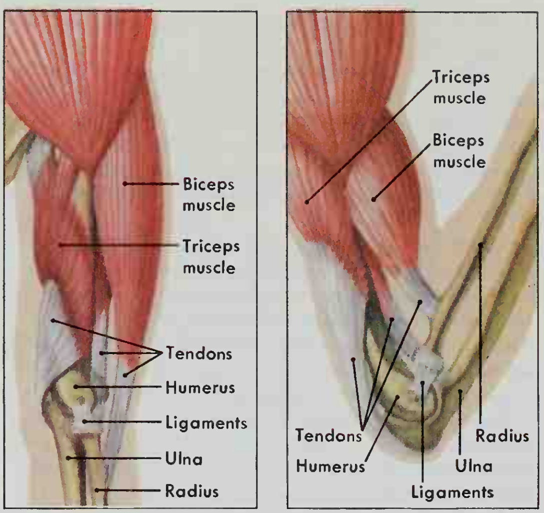
The Elbe River Basin contains some of Germany's best farmland and most important industrial regions. The river drains about 55,600 square miles (144,000 square kilometers) of land. Large oceangoing ships can travel on the Elbe from the North Sea as far as Hamburg, Germany—55 miles (89 kilometers) inland. At Hamburg, oceangoing ships transfer cargo to barges that sail the Elbe. Other important cities on the Elbe include Magdeburg and Dresden in Germany, and Ústí Nad Labem and Mělník in the Czech Republic. Major branches of the Elbe include the Saale and Havel rivers in Germany.
Leszek A. Kosiński

Elbow is the joint that connects a person's upper arm with the forearm. The *humerus*—the bone of the upper arm—and the *radius* and *ulna*—the bones of the forearm—meet at the elbow. The three bone connections form three smaller joints within the elbow joint. These smaller joints permit certain movements. The humerus-ulna joint and the humerus-radius joint allow a person to bend the forearm up and down. The radius-ulna joint and the humerus-radius joint permit a person to rotate the forearm and turn the palm of the hand up and down.

A *capsule* (pouch) of tough connective tissue surrounds the elbow joint. This capsule and several ligaments hold the bones in place. *Synovial fluid* reduces friction at the elbow. Excessive or violent twisting of the forearm may injure the elbow ligaments, capsule, or tendons. One such injury, sometimes called *tennis elbow,* often results from playing tennis.
Leslie S. Matthews

See also **Funny bone.**

El Camino Real, *EHL kah MEE noh ray AHL,* was an early California highway. It is Spanish for *The Royal Highway.* It ran north from San Diego for 530 miles (853 kilometers) to Sonoma to connect the Franciscan missions. By 1823, there were 21 missions along the road. Father Junípero Serra founded the first mission in San Diego in 1769. The mission at San Francisco, now called *Mission Dolores,* was built in 1776. United States Highway 101 closely follows the old route. *El Camino Real* is also the name of the first road established by Europeans in what is now the United States. It ran through what is now New Mexico. See **New Mexico** (Transportation).
Jerome O. Steffen



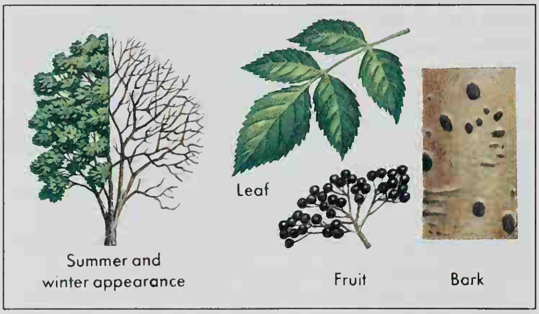
WORLD BOOK diagram by Lou Barlow

The elbow is the joint where the bone of the upper arm—the *humerus*—and the forearm bones—the *radius* and the *ulna*—meet. The elbow enables a person to "bend" his or her arm.

El Cid. See Cid, The.

Elder is the name of a group of 30 species of small trees or shrubs in the honeysuckle family. Elders grow in temperate areas of the Northern Hemisphere. Seven species are native to North America, five of which are tree-sized. The *American elder* is a shrub that grows in the eastern United States. Its leaves have 5 to 7 leaflets with toothed edges. The plants bear clusters of small white flowers and black, purple, or red berrylike fruit. The fruit is used to make wine, pies, jelly, and jam.

Elder stems contain a soft *pith* (core) that can be removed. The pith can be hollowed to make whistles and blowguns. The ancient Greeks made a musical instrument called a *sambuke* from the elder stem. The roots, stems, leaves, and unripe fruits of elders are poisonous.



WORLD BOOK illustration by John D. Dawson

An elder is a tree or shrub of the honeysuckle family. Its fruit, called elderberry, is sometimes used to make wine or pies.

Children have been poisoned from toys made from hollowed stems.

Elders thrive in moist areas. They grow quickly and often form thickets. Some other shrubs and trees are called elders, but they are not in the same family. The *poison elder* is a sumac, and the *boxelder* is a maple.

Scientific classification. Elders belong to the honeysuckle family, Caprifoliaceae. The American elder is *Sambucus canadensis.* Michael J. Baranski

El Dorado, *EHL duh RAH doh,* is the name of a fictitious kingdom of enormous wealth located in South America. Many European explorers searched for the kingdom, including Gonzalo Jiménez de Quesada of Spain and Sir Walter Raleigh of England. But none of the explorers found it. The term has become common for any legendary place of fabulous riches.

El Dorado, which means *the gilded* in Spanish, was originally the name of a legendary South American king whose body was regularly covered with gold dust. The king would float on a raft onto a lake while emeralds and gold objects were thrown into the lake. The legend probably referred to a similar ceremony performed by a Chibcha Indian chief in what is now the South American nation of Colombia. Helen Delpar

See **Colombia** (picture: *The Raft of El Dorado*).

Eleanor of Aquitaine, *AK wih TAYN* (1122-1204), was the wife of King Louis VII of France and later of King Henry II of England. She was also the mother of two English kings, Richard the Lion-Hearted and John. Her control of Aquitaine, then a vast independent state next to France, made her a central figure in the struggle for power between France and England.

Eleanor was the daughter of William X, Duke of Aquitaine. In 1137, when Eleanor was 15 years old, she inherited Aquitaine. Her land came under French control when she married Louis VII later that year. Eleanor and Louis had two daughters. But the lack of a male heir contributed to unhappiness in their marriage, and they agreed to a divorce in 1152.

Within months, Eleanor married Henry Plantagenet, who became King Henry II of England in 1154. Later, Eleanor and Henry lost affection for each other, and she supported a revolt against him in 1173. The revolt failed and Henry imprisoned Eleanor. Eleanor was freed in 1189, after Henry died and Richard became king. Eleanor greatly influenced both Richard and John during their reigns. Marion Meade

See also **Henry II** (king of England).

Elecampane, *EHL ee kam PAYN,* is a coarse perennial plant closely related to the asters. In many parts of the United States and Canada, it grows as a roadside weed. But people once widely cultivated the plant.

The heavy, fleshy root of the elecampane has a bitter taste similar to that of camphor. The root can be used as a remedy for coughs, colds, and bronchial ailments and as an aid to digestion. It can also be used to treat some skin diseases of horses. For this reason, elecampane is sometimes known as *horseheal.* Elecampane root is gathered in autumn of the second year of the plant's life. It is cleaned, sliced, and then dried for later use.

Scientific classification. Elecampane is in the composite family, Compositae. It is *Inula helenium.* Margaret R. Bolick

Election is the process by which people vote for the candidate or proposal of their choice. The basis of democratic government is that citizens have the right to choose the officials who will govern them. Elections thus rank as one of the most important political activities. Elections also serve as a means of peacefully transferring power from one person or group to another.

Most countries hold elections to select governmental officials. But in countries without democratic government, the people have little real choice. The only candidates allowed on the ballot are those approved by the leaders or by a single political party. In such countries, elections are held for propaganda reasons and to demonstrate popular support for the government.

In addition to public elections, nongovernmental elections are also held to select the officials of many organizations. Labor unions, social clubs, and the student bodies of schools hold elections to select their officers.

Elections in a democracy

Election procedures differ from country to country. However, certain principles characterize elections in democratic nations. In the United States, Canada, and other democratic countries, nearly all adults can vote. Those not permitted to vote include certain criminals and people with severe mental illness or mental retardation. Citizens vote by secret ballot so that they can vote without fear of how others will react. The mass media—which include radio, television, magazines, and newspapers—freely discuss the candidates and issues.

In most democratic countries, political parties select candidates for public office and propose public policies. However, in some countries and in parts of the United States, local elections are *nonpartisan*—that is, candidates appear on the ballot without being identified by political party.

Voters elect officials by either *direct* or *indirect* elections. In direct elections, the people themselves vote for public officials. In the United States, for example, citizens vote for members of Congress and for state and local officials in this way. In indirect elections, people

WORLD BOOK illustration by Susan Hillier

The elecampane plant is a common roadside weed.

elect representatives called *electors* to choose public officials. The U.S. President and Vice President are chosen in an indirect election. The voters of each state select electors, who make up the Electoral College. The electors in turn choose the President and Vice President based on the popular vote in the states they represent.

Under a parliamentary system of government, also called a *cabinet system,* citizens elect members of the legislature. The head of state—the king or queen of a monarchy or the president of a republic—then selects a prime minister from the members of the legislature. Australia, Canada, and certain other Commonwealth nations regard the British ruler as head of state. In such nations, the governor general makes the appointment, acting as the representative of the monarch. In most countries, the head of state can appoint only the leader of the majority party in the legislature or the head of a coalition of parties. See **Cabinet** (The cabinet system of government).

Elections in the United States

Election regulations. The Constitution of the United States requires that a congressional election be held every two years. At that time, voters elect all the members of the House of Representatives for a two-year term and about one-third of the Senate members for a six-year term. The Constitution also requires the election of a President and a Vice President every four years. Federal law states that national elections are to be held on the first Tuesday after the first Monday of November.

State laws regulate all elections, including national and local ones. Such laws establish the eligibility requirements for state officials and the date on which state and local elections are to be held. They also establish the qualifications for voters. However, the Constitution gives Congress the right to change state voter requirements if they violate constitutional guarantees.

Nomination of candidates. At one time, political parties nominated nearly all candidates at national, state, and local conventions or in closed meetings of party members called *caucuses.* Today, candidates for most state and local offices are nominated in *direct primary elections.* A direct primary is a contest in which voters choose the candidates who will represent each political party in the upcoming general election. Other candidates may run in the general election, where voters make their final choice. However, only the candidates who win the primaries become official party nominees. A *runoff election* may be held if no candidate in the original primary receives more than half the vote. The two candidates with the most votes run against each other, and the winner becomes the party nominee.

The qualifications for voting in a direct primary election vary according to whether the primary is closed or open. In a *closed primary,* voters must declare a choice of party, either when registering to vote or when receiving their ballot. They must then choose from among the candidates on their party's ballot. In an *open primary,* voters may cast their ballot for candidates of any party. Voters receive ballots for all parties in the election, mark one in the voting booth, and discard the rest.

Each party holds a national convention to nominate its presidential and vice presidential candidates. Many states hold special primary elections to choose delegates to those conventions. In some states, the ballot lists presidential candidates. In others, it lists proposed delegates, who may have promised to support a certain candidate. Voters can support a candidate by voting for that person's delegates. In still other states, local caucuses choose delegates to the national convention.

Election procedures. Most elections are supervised on the local level by county election officials, who divide each county or ward into voting districts called *precincts.* Election officials determine the place where votes will be cast, called the *polling place* or the *polls.* They also check voters' names against registration lists, hand out ballots, and supervise the depositing of marked ballots in ballot boxes. In most states, the officials at each polling place must represent the two major political parties. In some areas, citizens' groups station observers called *poll watchers* at the polls to ensure that election officials perform their tasks honestly.

Voters indicate their choices privately in an enclosed voting booth. Many precincts use voting machines that automatically record votes. Every state allows certain citizens to vote by absentee ballot before the election. These citizens include people in the armed services, college students, sick persons, and certain travelers.

The polls generally remain open from early morning until evening on Election Day. After the polls close, election officials count the votes for each candidate, including absentee votes. Then, all ballots and tally sheets from voting machines are sent, under seal, to city or county officials or to the board of elections. All state and national election results are filed with the chief election official, the secretary of state in most states. State and local officials then declare the winners in each race. Federal and state laws define dishonest voting practices and provide severe penalties for them. Such practices include bribing voters, impersonating another voter, stuffing a ballot box with forged votes, and tampering with voting machines. Laws also prohibit election officials from tampering with election results. Robert Agranoff

Related articles in *World Book* include:

Ballot	Electoral college	Recall
Corrupt practices	Initiative and referendum	Voting
Election campaign	Primary election	Voting machine
Election day		

Election campaign is a series of operations designed to win votes for a certain candidate, party, or proposal. In the United States, the best-known campaign is the one for President held every four years. However, thousands of other campaigns—including those for Congress, state legislatures, city councils, and school boards—take place in a year. Still other campaigns involve a *referendum,* the process of submitting a proposal to the voters for approval.

What a candidate needs to campaign

A campaign organization consists of paid staff members and consultants, and unpaid volunteers. A presidential campaign may involve as many as 500 staff members and millions of volunteers. A campaign director heads the organization and coordinates all activities. Other officials of a large campaign include a general manager, a research director, a finance director, and a *media director,* who supervises advertising and publicity. Most candidates visit a number of communities,

and specialists called *advance people* travel ahead to make the arrangements. Professional consultants help plan and conduct various operations. For example, many candidates employ a polling organization to take public opinion polls. Many also hire an advertising agency to create advertisements and a direct-mail marketing firm to raise funds and target appeals to voters.

Volunteers distribute leaflets, prepare mailings, call voters, and perform many other tasks. In small campaigns, volunteers also fill many of the top positions. A campaign headquarters has office machines, telephones, and computers for workers to use.

Campaign funds are necessary to pay personnel and to finance advertising, travel, and other needs. The chief sources of funds are *personal solicitations, appeals by direct mail, fund-raising events,* and *matching funds*.

Personal solicitations are individual requests by the candidate or a campaign worker. The majority of candidates raise most of their funds by soliciting donations from supporters, associates, and friends, and from members of their own family. Appeals by direct mail involve fund-raising letters sent to party members, people who have contributed to past campaigns, and members of groups likely to agree with the candidate's views. Fund-raising events include parties and dinners. Matching funds are government payments that match the private contributions raised by candidates. Matching funds are available only to candidates who meet certain fund-raising requirements.

Candidates also receive gifts of money from many organizations, but federal law prohibits corporations and labor unions from making direct political contributions. Instead, many such organizations establish panels called *political action committees* (PAC's). A PAC collects voluntary contributions from the organization's employees or members and gives the money to candidates it favors.

During much of the 1900's, federal laws regulated who could contribute money to campaigns and limited the amount that an individual or group could contribute to any one candidate. However, qualified individuals and groups could still make unlimited donations into general political party funds. These donations became known as *soft money*. Many critics argued that unregulated soft money donations allowed donors to use money to gain political influence. A federal law passed in 2002 banned soft money donations to the national political parties and placed limits on such donations to state and local party organizations.

Stages of a campaign

Most election campaigns start months before the public knows the candidates are running. A candidate asks community and party leaders and possible contributors if they will give their support. In major campaigns, polls also indicate the possible support for a candidate. If the candidate and his or her advisers think they have enough backing, they begin to develop strategy.

Planning campaign strategy. Most campaign strategy is based on information provided by research. Campaign planners study such economic and social conditions as the area's industrial production and the age distribution of the people. They use such information, along with data from public opinion polls and the results of previous elections, to determine key issues and areas of possible strength and weakness. Then the planners choose their *targets*—the people at whom the campaign will be aimed. The candidate and his or her advisers develop positions on issues that are likely to be discussed during the campaign. They may write a series of statements called *position papers* to explain the candidate's views. They also begin to raise funds, recruit volunteers, and purchase advertising.

Announcing the candidacy marks the official start of a campaign. Most candidates hold a news conference to make their announcement. Candidates may tour their state or district and repeat their declaration several times through the media in different geographic areas.

Developing support. The pace quickens after the announcement of candidacy, and the campaign becomes more apparent to the public. The campaign organization holds meetings and fund-raising events. Signs and bumper stickers appear. The candidates and their workers strive to develop voter support through publicity, advertising, and personal appearances.

Candidates reach the greatest number of people through the media. For example, candidates issue news releases, grant interviews, hold news conferences, and appear on televised debates and talk shows. Candidates also purchase advertising, including appeals on billboards, commercials on television and radio, and advertisements in newspapers. Most campaigns use a *media mix,* which is a combination of these methods.

A candidate spends much time making speeches and other personal appearances. Campaign officials encourage newspaper and television coverage of each appearance. In addition, they may present themselves and their ideas in large blocks of program time that they have purchased on radio or TV.

Winning the nomination. Most major presidential candidates seek to be nominated for president by a political party. These candidates must run against one or more other members of their party to win the nomination. The two major U.S. parties, the Democrats and the Republicans, hold national conventions to officially select their nominees for president and vice president. In some states, a state or district convention of party members selects delegates to the national convention. To get the support of national delegates from those states, a presidential candidate must first win the backing of delegates to the state or district convention. Some states hold local party meetings called *caucuses* to select national, state, or district delegates.

Many states hold primary elections to choose delegates to each party's national convention (see **Primary election**). But changes in state laws and party rules have encouraged the direct selection of presidential nominees by primary voters. Presidential primaries are held early in election years, and candidates must gain voter support in primaries to contend for the nomination. Primary elections also determine who will represent the party in contests for most other offices. In most states, independent candidates and minor-party candidates get on the ballot by filing a petition signed by a specified number of voters.

Getting out the vote. As Election Day approaches, the pace of the campaign becomes hectic. Candidates issue daily news releases and flood the media with advertising. Campaign workers visit voters again and

again, and rallies are held continually.

Much of the activity during this period is devoted to getting out the vote. In a process called *canvassing,* volunteers call or visit voters to ask which candidates they favor. The campaign workers then try to make sure that the probable supporters of their candidate will vote. They encourage all supporters to register to vote.

On Election Day, campaign workers provide transportation and baby-sitting service for voters. Volunteers at the polls keep track of supporters who have voted and contact those who have not done so. Other volunteers observe the voting and the counting of ballots to discourage fraud. Robert Agranoff

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Advertising (Political effects)	Political party
Caucus	President of the United States (The presidential election; pictures)
Corrupt practices	Primary election
Election	Public opinion poll
Federal Election Commission	Television (Effects on society)
Political action committee	
Political convention	

Additional resources

Moore, John L. *Elections A to Z.* Congressional Quarterly, 1999.
Rose, Richard, ed. *International Encyclopedia of Elections.* C Q Pr., 2000.

Election Day in the United States is the day on which national elections for presidential electors take place. The U.S. Congress established the first Tuesday after the first Monday in November as Election Day. It is a legal holiday in most states and in all territories. Many state elections are also held on this day. Many states forbid the retail sale of liquor while the polls are open.

Originally, Congress did not set a specific date for national elections. Each state could appoint its electors on any day within 34 days before the date in December set for the convening of electors. In 1845, Congress established Election Day to correct abuses caused by the lack of a standard election day. Robert Agranoff

Election of 2000 was one of the closest and most unusual presidential elections in United States history. The outcome—that Republican George W. Bush defeated his Democratic opponent Al Gore—remained in doubt for five weeks after the election. The winner received more electoral votes but fewer popular votes than his opponent. A decision by the Supreme Court of the United States led to the final resolution of the contest.

On Election Day, November 7, more than 100 million U.S. citizens went to the polls. The race was extremely close between Texas Governor George W. Bush and Vice President Al Gore. Gore led in the popular vote and had a narrow lead over Bush in electoral votes (see **Electoral College**). In Florida, however, where the results had not yet been finalized, the race was particularly close. It became obvious that the election depended upon who received Florida's 25 electoral votes.

Early in the evening, television newscasters predicted that Gore would win Florida. But official tallies from the state showed an increasing number of votes for Bush. As a result, the television networks retracted their original prediction and declared Bush the winner in Florida.

Gore called Bush to concede the election. But shortly after the call, Bush's lead in Florida began to shrink. The networks said the vote in Florida was too close to predict. Gore called Bush to retract his concession.

Recounts. On the morning of November 8, Gore led Bush in popular votes, but the winner of the electoral votes was still unknown. The count in Florida showed Bush ahead of Gore by nearly 1,800 votes out of about 6 million cast. In the case of such a close vote, Florida law called for a recount. Before the machine recount was completed, Gore requested a recount by hand as well in four Florida counties, where results were in dispute.

Court challenges. Gore sought support in the courts for the manual recounts. He argued that a recount by hand was the only way to make sure every person's vote was included in the final tally. He pointed out that machines did not count partially punched ballots. On such ballots, the *chad,* a small piece of paper that covered the punch hole, was not completely removed.

Bush fought through the courts to halt the recounts. He insisted that the process was less fair and less precise than a machine count because of the human judgment involved.

Some early court rulings allowed the recounts to continue. On November 13, for example, a federal judge in Miami rejected Bush's request to stop the recounts. On November 15, the Florida Supreme Court allowed more time for the recounts to be completed by changing the deadline from November 14 to November 26.

Miami-Dade County voting officials halted their recount, saying that even with the extended deadline, there would not be time to manually recount all the votes. Broward and Volusia counties met the deadline. Palm Beach County continued its recount but did not finish in time. Florida Secretary of State Katherine Harris refused to accept the tally because it was submitted about two hours after the deadline. On November 26, Harris certified a Florida win for Bush with a margin of 537 votes. Gore contested the certified vote.

Bush v. Gore. When Gore's contest of the certified vote came before the Florida Supreme Court, the court ordered a manual recount of all state ballots on which no vote for president had been registered by machine. Bush appealed the ruling to the U.S. Supreme Court. On December 12, the Supreme Court justices, voting 5 to 4 in the case of *Bush v. Gore,* ruled that the Florida recounts should not continue. They said the various vote-counting standards being used from county to county violated the Constitution's guarantee that all citizens are entitled to "equal protection of the laws." They also ruled there was not enough time to develop a consistent statewide standard and perform a manual recount.

The outcome. In a televised address to the nation on December 13, 36 days after the election, Gore conceded the election to Bush. Official figures for the popular vote showed that Gore defeated Bush by a total of 539,898 votes. Gore, with 50,996,039 votes, received 48.38 percent of the popular vote. Bush received 50,456,141 votes and 47.87 percent of the popular vote. But Bush defeated Gore 271 to 266 in electoral votes, with one elector not casting a vote. In January 2001, George W. Bush became the nation's 43rd president. Barbara Lanctot

Electoral College is a group of representatives chosen by the voters of each state to elect the president and vice president of the United States. The U.S. Constitution created the Electoral College.

Every state has as many votes in the Electoral College as the total of its senators and representatives in Con-

Electoral College

The Electoral College is a group chosen by the voters of each state to elect the president of the United States. This chart shows how the college has voted since 1804, when the present system was adopted. The House of Representatives decided the 1824 election because no one won a majority. In 1872, the electoral votes of Arkansas and Louisiana were disputed and not counted.

5 Democratic

5 Republican

Year	Candidate elected	Winner's total	Total vote	Ala.	Alaska	Ariz.	Ark.	Calif.	Colo.	Conn.	Del.	D.C.	Fla.	Ga.	Hawaii	Ida.	Ill.	Ind.	Iowa	Kans.	Ky.	La.	Me.	Md.	Mass.	Mich.	Minn.	Miss.	Mo.	Mont.	Nebr.	Nev.	N.H.
1804	Jefferson	162	176							9	3			6							8			/	19								7
1808	Madison	122	175							9	3			6							7			/	19								7
1812	Madison	128	217							9	4			8							12	3		/	22								8
1816	Monroe	183	217							9	3			8				3			12	3		8	22								8
1820	Monroe	231	232	3						9	4			8			3	3			12	3	9	11	15			2	3				/
1824	J. Q. Adams	84	261							8	1						1					2	9	3	15								8
1828	Jackson	178	261	5						8	3			9			3	5			14	5	/	/	15			3	3				8
1832	Jackson	219	286	7						8	3			11			5	9			15	5	10	/	14			4	4				7
1836	Van Buren	170	294	7			3			8	3			11			5	9			15	5	10	10	14	3		4	4				7
1840	W. Harrison	234	294	7			3			8	3			11			5	9			15	5	10	10	14	3		4	4				7
1844	Polk	170	275	9			3			6	3			10			9	12			12	6	9	8	12	5		6	7				6
1848	Taylor	163	290	9			3			6	3		3	10			9	12	4		12	6	9	8	12	5		6	7				6
1852	Pierce	254	296	9			4	4		6	3		3	10			11	13	4		12	6	8	8	13	6		7	9				5
1856	Buchanan	174	296	9			4	4		6	3		3	10			11	13	4		12	6	8	8	13	6		7	9				5
1860	Lincoln	180	303	9			4	4		6	3		3	10			11	13	4		12	6	8	8	13	6	4	7	9				5
1864	Lincoln	212	233					5		6	3						16	13	8	3	11		7	7	12	8	4		11			2	5
1868	Grant	214	294	8			5	5		6	3		3	9			16	13	8	3	11	7	7	7	12	8	4		11		3	3	5
1872	Grant	286	349	10				6		6	3		4	/			21	15	11	5	/		7	8	13	11	5	8	/		3	3	5
1876	Hayes	185	369	10			6	6	3	6	3		4	11			21	15	11	5	12	8	7	8	13	11	5	8	15		3	3	5
1880	Garfield	214	369	10			6	/	3	6	3		4	11			21	15	11	5	12	8	7	8	13	11	5	8	15		3	3	5
1884	Cleveland	219	401	10			7	8	3	6	3		4	12			22	15	13	9	13	8	6	8	14	13	7	9	16		5	3	4
1888	B. Harrison	233	401	10			7	8	3	6	3		4	12			22	15	13	9	13	8	6	8	14	13	7	9	16		5	3	4
1892	Cleveland	277	444	11			8	/	4	6	3		4	13		3	24	15	13	10	13	8	6	8	15	/	9	9	17	3	8	3	4
1896	McKinley	271	447	11			8	/	4	6	3		4	13		3	24	15	13	10	/	8	6	8	15	14	9	9	17	3	8	3	4
1900	McKinley	292	447	11			8	9	4	6	3		4	13		3	24	15	13	10	13	8	6	8	15	14	9	9	17	3	8	3	4
1904	T. Roosevelt	336	476	11			9	10	5	7	3		5	13		3	27	15	13	10	13	9	6	/	16	14	11	10	18	3	8	3	4
1908	Taft	321	483	11			9	10	5	7	3		5	13		3	27	15	13	10	13	9	6	/	16	14	11	10	18	3	8	3	4
1912	Wilson	435	531	12		3	9	/	6	7	3		6	14		4	29	15	13	10	13	10	6	8	18	15	12	10	18	4	8	3	4
1916	Wilson	277	531	12		3	9	13	6	7	3		6	14		4	29	15	13	10	13	10	6	8	18	15	12	10	18	4	8	3	4
1920	Harding	404	531	12		3	9	13	6	7	3		6	14		4	29	15	13	10	13	10	6	8	18	15	12	10	18	4	8	3	4
1924	Coolidge	382	531	12		3	9	13	6	7	3		6	14		4	29	15	13	10	13	10	6	8	18	15	12	10	18	4	8	3	4
1928	Hoover	444	531	12		3	9	13	6	7	3		6	14		4	29	15	13	10	13	10	6	8	18	15	12	10	18	4	8	3	4
1932	F. Roosevelt	472	531	11		3	9	22	6	8	3		7	12		4	29	14	11	9	11	10	5	8	17	19	11	9	15	4	7	3	4
1936	F. Roosevelt	523	531	11		3	9	22	6	8	3		7	12		4	29	14	11	9	11	10	5	8	17	19	11	9	15	4	7	3	4
1940	F. Roosevelt	449	531	11		3	9	22	6	8	3		7	12		4	29	14	11	9	11	10	5	8	17	19	11	9	15	4	7	3	4
1944	F. Roosevelt	432	531	11		4	9	25	6	8	3		8	12		4	28	13	10	8	11	10	5	8	16	19	11	9	15	4	6	3	4
1948	Truman	303	531	11		4	9	25	6	8	3		8	12		4	28	13	10	8	11	10	5	8	16	19	11	9	15	4	6	3	4
1952	Eisenhower	442	531	11		4	8	32	6	8	3		10	12		4	27	13	10	8	10	10	5	9	16	20	11	8	13	4	6	3	4
1956	Eisenhower	457	531	/		4	8	32	6	8	3		10	12		4	27	13	10	8	10	10	5	9	16	20	11	8	13	4	6	3	4
1960	Kennedy	303	537	/	3	4	8	32	6	8	3		10	12	3	4	27	13	10	8	10	10	5	9	16	20	11	8	13	4	6	3	4
1964	L. Johnson	486	538	10	3	5	6	40	6	8	3	3	14	12	4	4	26	13	9	7	9	10	4	10	14	21	10	7	12	4	5	3	4
1968	Nixon	301	538	10	3	5	6	40	6	8	3	3	14	12	4	4	26	13	9	7	9	10	4	10	14	21	10	7	12	4	5	3	4
1972	Nixon	520	538	9	3	6	6	45	7	8	3	3	17	12	4	4	26	13	8	7	9	10	4	10	14	21	10	7	12	4	5	3	4
1976	Carter	297	538	9	3	6	6	45	7	8	3	3	17	12	4	4	26	13	8	7	9	10	4	10	14	21	10	7	12	4	5	3	4
1980	Reagan	489	538	9	3	6	6	45	7	8	3	3	17	12	4	4	26	13	8	7	9	10	4	10	14	21	10	7	12	4	5	3	4
1984	Reagan	525	538	9	3	7	6	47	8	8	3	3	21	12	4	4	24	12	8	7	9	10	4	10	13	20	10	7	11	4	5	4	4
1988	G. H. W. Bush	426	538	9	3	7	6	47	8	8	3	3	21	12	4	4	24	12	8	7	9	10	4	10	13	20	10	7	11	4	5	4	4
1992	Clinton	370	538	9	3	8	6	54	8	8	3	3	25	13	4	4	22	12	7	6	8	9	4	10	12	18	10	7	11	3	5	4	4
1996	Clinton	379	538	9	3	8	6	54	8	8	3	3	25	13	4	4	22	12	7	6	8	9	4	10	12	18	10	7	11	3	5	4	4
2000	G. W. Bush	271	538	9	3	8	6	54	8	8	3	/	25	13	4	4	22	12	7	6	8	9	4	10	12	18	10	7	11	3	5	4	4

- 5 Democratic-Republican
- 5 Federalist
- 5 National Republican
- 5 Whig
- 5 Progressive
- 5 Other parties
- / Split vote
- Not voting

N.J.	N.Mex.	N.Y.	N.C.	N.Dak.	Ohio	Okla.	Ore.	Pa.	R.I.	S.C.	S.Dak.	Tenn.	Tex.	Utah	Vt.	Va.	Wash.	W.Va.	Wis.	Wyo.	Year
8		19	14		3			20	4	10		5			6	24					1804
8		/	/		3			20	4	10		5			6	24					1808
8		29	15		7			25	4	11		8			8	25					1812
8		29	15		8			25	4	11		8			8	25					1816
8		29	15		8			24	4	11		7			8	25					1820
		26							4						7						1824
8		/	15		16			28	4	11		11			7	24					1828
8		42	15		21			30	4	11		15			7	23					1832
8		42	15		21			30	4	11		15			7	23					1836
8		42	15		21			30	4	11		15			7	23					1840
7		36	11		23			26	4	9		13			6	17					1844
7		36	11		23			26	4	9		13	4		6	17			4		1848
7		35	10		23			27	4	8		12	4		5	15			5		1852
7		35	10		23			27	4	8		12	4		5	15			5		1856
/		35	10		23		3	27	4	8		12	4		5	15			5		1860
7		33			21		3	26	4						5			5	8		1864
7		33	9		21		3	26	4	6		10			5			5	8		1868
9		35	10		22		3	29	4	7		12	8		5	11		5	10		1872
9		35	10		22		3	29	4	7		12	8		5	11		5	10		1876
9		35	10		22		3	29	4	7		12	8		5	11		5	10		1880
9		36	11		23		3	30	4	9		12	13		4	12		6	11		1884
9		36	11		23		3	30	4	9		12	13		4	12		6	11		1888
10		36	11	/	/		/	32	4	9	4	12	15		4	12	4	6	12	3	1892
10		36	11	3	23		4	32	4	9	4	12	15	3	4	12	4	6	12	3	1896
10		36	11	3	23		4	32	4	9	4	12	15	3	4	12	4	6	12	3	1900
12		39	12	4	23		4	34	4	9	4	12	18	3	4	12	5	7	13	3	1904
12		39	12	4	23	7	4	34	4	9	4	12	18	3	4	12	5	7	13	3	1908
14	3	45	12	5	24	10	5	38	5	9	5	12	20	4	4	12	7	8	13	3	1912
14	3	45	12	5	24	10	5	38	5	9	5	12	20	4	4	12	7	/	13	3	1916
14	3	45	12	5	24	10	5	38	5	9	5	12	20	4	4	12	7	8	13	3	1920
14	3	45	12	5	24	10	5	38	5	9	5	12	20	4	4	12	7	8	13	3	1924
14	3	45	12	5	24	10	5	38	5	9	5	12	20	4	4	12	7	8	13	3	1928
16	3	47	13	4	26	11	5	36	4	8	4	11	23	4	3	11	8	8	12	3	1932
16	3	47	13	4	26	11	5	36	4	8	4	11	23	4	3	11	8	8	12	3	1936
16	3	47	13	4	26	11	5	36	4	8	4	11	23	4	3	11	8	8	12	3	1940
16	4	47	14	4	25	10	6	35	4	8	4	12	23	4	3	11	8	8	12	3	1944
16	4	47	14	4	25	10	6	35	4	8	4	/	23	4	3	11	8	8	12	3	1948
16	4	45	14	4	25	8	6	32	4	8	4	11	24	4	3	12	9	8	12	3	1952
16	4	45	14	4	25	8	6	32	4	8	4	11	24	4	3	12	9	8	12	3	1956
16	4	45	14	4	25	/	6	32	4	8	4	11	24	4	3	12	9	8	12	3	1960
17	4	43	13	4	26	8	6	29	4	8	4	11	25	4	3	12	9	7	12	3	1964
17	4	43	/	4	26	8	6	29	4	8	4	11	25	4	3	12	9	7	12	3	1968
17	4	41	13	3	25	8	6	27	4	8	4	10	26	4	3	/	9	6	11	3	1972
17	4	41	13	3	25	8	6	27	4	8	4	10	26	4	3	12	/	6	11	3	1976
17	4	41	13	3	25	8	6	27	4	8	4	10	26	4	3	12	9	6	11	3	1980
16	5	36	13	3	23	8	7	25	4	8	3	11	29	5	3	12	10	6	11	3	1984
16	5	36	13	3	23	8	7	25	4	8	3	11	29	5	3	12	10	/	11	3	1988
15	5	33	14	3	21	8	7	23	4	8	3	11	32	5	3	13	11	5	11	3	1992
15	5	33	14	3	21	8	7	23	4	8	3	11	32		3		11		11	3	1996
15	5	33	14	3	21	8	7	23	4	8	3	11	32	5	3	13	11	5	11	3	2000

Splits in state electoral votes

In most elections, the candidate who wins the highest number of a state's popular votes receives all the state's electoral votes. In some elections, however, Electoral College members from the same state have voted for different candidates. This situation is shown by a slash mark (/) in the table on these two pages. Since 1804, the following splits in electoral votes have occurred:

Election	State's total vote and split
1804	Maryland 11 (Jefferson 9, Charles C. Pinckney 2).
1808	Maryland 11 (Madison 9, Pinckney 2); New York 19 (Madison 13, George Clinton 6); North Carolina 14 (Madison 11, Pinckney 3).
1812	Maryland 11 (Madison 6, Clinton 5).
1820	New Hampshire 8 (Monroe 7, J. Q. Adams 1).
1828	Maine 9 (J. Q. Adams 8, Jackson 1); Maryland 11 (J. Q. Adams 6, Jackson 5); New York 36 (Jackson 20, J. Q. Adams 16).
1832	Maryland 8 (Henry Clay 5, Jackson 3).
1860	New Jersey 7 (Lincoln 4, Stephen A. Douglas 3).
1872	Georgia 8 (Benjamin G. Brown 6, Charles J. Jenkins 2); Kentucky 12 (Thomas A. Hendricks 8, Brown 4); Missouri 15 (Brown 8, Hendricks 6, David Davis 1).
1880	California 6 (Winfield Scott Hancock 5, Garfield 1).
1892	California 9 (Cleveland 8, B. Harrison 1); Michigan 14 (B. Harrison 9, Cleveland 5); North Dakota 3 (Cleveland 1, B. Harrison 1, James B. Weaver 1); Ohio 23 (B. Harrison 22, Cleveland 1); Oregon 4 (B. Harrison 3, Weaver 1).
1896	California 9 (McKinley 8, William Jennings Bryan 1); Kentucky 13 (McKinley 12, Bryan 1).
1904	Maryland 8 (Alton B. Parker 7, T. Roosevelt 1).
1908	Maryland 8 (Bryan 6, Taft 2).
1912	California 13 (T. Roosevelt 11, Wilson 2).
1916	West Virginia 8 (Charles E. Hughes 7, Wilson 1).
1948	Tennessee 12 (Truman 11, Strom Thurmond 1).
1956	Alabama 11 (Adlai E. Stevenson 10, Walter B. Jones 1).
1960	Alabama 11 (Harry F. Byrd 6, Kennedy 5); Oklahoma 8 (Nixon 7, Byrd 1).
1968	North Carolina 13 (Nixon 12, George C. Wallace 1).
1972	Virginia 12 (Nixon 11, John Hospers 1).
1976	Washington 9 (Ford 8, Reagan 1).
1988	West Virginia 6 (Michael S. Dukakis 5, Lloyd Bentsen 1).
2000	D.C. 3 (Al Gore 2; one elector did not vote).

gress. Amendment 23 to the U.S. Constitution, ratified in 1961, gave the District of Columbia three electoral votes. The table with this article shows how the size of the college has changed. It also shows how the states have voted since 1804, when the present system of electing the president was adopted. State committees or conventions of each political party usually select the candidates for presidential electors. In some states, the ballots list the presidential and vice presidential candidates, but do not list the proposed electors. For this reason, many voters do not realize they do not vote directly for the president and vice president. In the election, the candidate who wins a *plurality* (the highest number) of a state's popular votes usually receives all the state's electoral votes. Thus, a candidate may be elected to the presidency with-

out a majority of the popular votes.

The College in action. In the December following the presidential election, on a day set by law, the presidential electors in each state and the District of Columbia assemble. State electors usually meet in their state's capital. The electors then cast their ballots for president and vice president. Either by custom or, in a few states, by law, electors vote for their party's choices for the two offices. The lists of these elections are sent under seal to the president of the U.S. Senate and to the Administrator of General Services in Washington, D.C.

In January, at a joint session in the House of Representatives, the president of the Senate opens the certificates. Then one Democrat and one Republican from each house count the votes in the presence of both houses of Congress. The candidate who gets a majority of the electoral votes for president is declared elected.

If no candidate has a majority, the state delegations in the House of Representatives choose the president from the three candidates who have the highest number of electoral votes. Each state has one vote in such an election. If no candidate wins a majority of the electoral votes for vice president, the Senate elects the vice president. It chooses between the two people with the most votes.

Reasons for the Electoral College. The manner of electing the president was a major problem at the Constitutional Convention of 1787. The convention rejected the proposal that Congress elect the chief executive, on the grounds that the president would then be under the control of the legislature. The proposal that the people elect the president also was rejected. To solve this problem and promote calm deliberation, the convention agreed on the method of indirect popular election, which became the Electoral College.

History. From 1789 to 1801, each elector voted for two people on the same ballot. In 1789, all 69 electors voted for George Washington, and 34 voted for John Adams. The rest of the votes were for other candidates. Adams became vice president because in those days the runner-up took that position.

By 1800, two political parties had emerged. In that year, two Democratic-Republican candidates, Thomas Jefferson and Aaron Burr, both got a majority of the electoral vote and tied for first place. The election went to the House of Representatives, where each state had one vote. Jefferson was elected president, and Burr became vice president. That election led to Amendment 12 to the Constitution, ratified in 1804, providing that electors should designate their votes for president and vice president on separate ballots.

The House had to settle another presidential election in 1824. Andrew Jackson received more electoral votes than any of the other three candidates but failed to win a majority. John Quincy Adams was the runner-up. In the House, Henry Clay, another candidate, threw his support to Adams. Adams became president in spite of Jackson's bigger popular vote.

According to the United States Constitution, each state legislature decides how that state's electors shall be chosen. At first, most states allowed their legislatures to choose the electors. After 1800, more and more states began choosing electors in popular elections. Today, all states and the District of Columbia use this method.

The development of political parties over the years has reduced the Electoral College to a routine ceremony. Electors have made an implied pledge to vote for their party's nominees, instead of the candidate that they personally think is best qualified for office. This implied pledge has seldom been broken.

Frequent proposals have been made for abolishing the Electoral College and for the direct election of the president. These amendments would tend to reduce the importance of the states in the federal system. It has been claimed that direct election might encourage third and fourth parties. But this, in turn, might often result in the election of a president who received only a minority of the popular votes. Opponents of the Electoral College point out that the system has allowed four candidates to become president whose closest opponent received more popular votes. The four were John Quincy Adams in 1824, Rutherford B. Hayes in 1876, Benjamin Harrison in 1888, and George W. Bush in 2000. Robert Agranoff

Related articles. See the separate biography on each U.S. president for election information. See also:

Constitution of the United States (Article II; Amendment 12)
Electoral Commission
President of the U.S.
Primary election
Vice president of the United States

Additional resources

Hardaway, Robert M. *The Electoral College and the Constitution.* Praeger, 1994.
Henry, Christopher E. *The Electoral College.* Watts, 1996. Younger readers.
Longley, Lawrence D., and Peirce, Neal R. *The Electoral College Primer 2000.* Yale, 1999.

Electoral Commission was a group created by Congress in 1877 to decide who won the presidential election of 1876. Both Republicans and Democrats claimed victory. Samuel J. Tilden, the Democratic candidate, had 184 electoral votes, or one short of a majority in the Electoral College. Rutherford B. Hayes, the Republican candidate, had 165 votes. Twenty votes were disputed.

To settle the matter, Congress created the Electoral Commission. The commission was made up of 15 members: 5 senators, 5 representatives, and 5 Supreme Court justices. Congress carefully arranged that 3 senators and 2 representatives were to be Republicans, while 2 senators and 3 representatives were to be Democrats. Of the justices, 2 Democrats and 2 Republicans were named, and these 4 had power to choose a fifth. They would probably have chosen David Davis of Illinois, an independent in politics. However, his decision to accept election to the United States Senate left only Republican justices from whom to choose. As a result, the Electoral Commission had a Republican majority of 8 to 7. By a strict party vote, the commission gave every one of the disputed votes, and the election, to Hayes.

H. Wayne Morgan

See also **Electoral College; Hayes, Rutherford Birchard** (The election dispute); **Tilden, Samuel Jones.**

Electra, *ih LEHK truh,* in Greek mythology was famous for her loyalty to her father, the Greek leader Agamemnon. Clytemnestra, who was Electra's mother, and Clytemnestra's lover, Aegisthus, murdered Agamemnon. Electra sent Orestes, her younger brother, from the royal palace to protect him from Clytemnestra. Electra hated her mother, but lived with her and Aegisthus until

Orestes was grown. Orestes then returned from exile to avenge the death of his father, killing Clytemnestra and Aegisthus with Electra's help. Electra is a central character in tragedies by the Greek playwrights Aeschylus, Sophocles, and Euripides.

The Swiss psychologist Carl Jung originated the term *Electra complex.* He used it to describe a girl's excessive attachment to her father and corresponding hostility toward her mother. John Hamilton

See also **Agamemnon**; **Clytemnestra**.

Electra complex. See **Oedipus complex**.

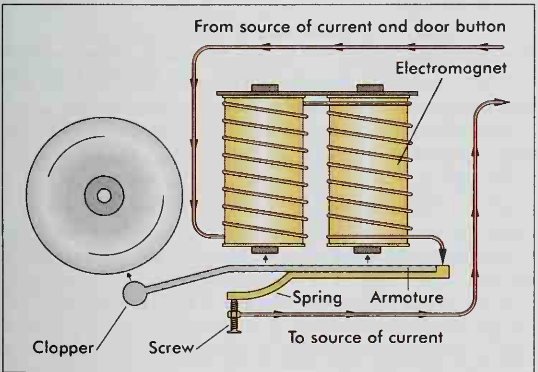
Electric arc is a curve of intense heat and light formed when a strong electric current leaps across a gap between two electrodes. Gases in the air between the electrodes serve as a conductor and transmit the current across the gap. Sir Humphry Davy, an English chemist, discovered the principle of the electric arc about 1808. Today, electric arcs are used in arc lights and arc welding. Electric arcs may also serve as ion sources in *particle accelerators,* devices that are used to study nuclear and elementary particles. Robert B. Prigo

See also **Welding** (Arc welding); **Rocket** (Electric rockets).

Electric bell is a type of bell operated by an electric current. There are two types of electric bells. One type rings continuously when the switch that controls it is on. This type of bell is commonly used in schools and factories. The other kind, the door chime, rings only once or twice when the switch is turned on—that is, when the doorbell button is pushed.

The parts of a continuously ringing bell include the switch; an electromagnet, a device that acts as a magnet when a current runs through it; and an *armature,* a movable metal part. A clapper is attached to the end of the armature. Also attached to the armature is a spring that rests against a screw. Wiring runs from the source of electric current to the switch and from the switch to the electromagnet. Another wire runs from the screw back to the source of the electric current. Together, the parts of the bell form an electric circuit.

When the switch is turned on, the current flows through the electromagnet, and the electromagnet attracts the armature. The movement of the armature causes the clapper to strike the bell and the spring to move off the screw. When the spring moves off the screw, the circuit is broken and the current stops flowing. Then, the armature falls away from the electromagnet. When the armature returns to its original position, the spring comes in contact with the screw again and reestablishes the flow of electric current. The process repeats, and the electric bell keeps ringing as long as the operating switch is on.



WORLD BOOK diagram by Kim Downing

An electric bell rings when a current flows through its electromagnet. The current makes the electromagnet attract the metal armature, which causes the clapper to strike the bell.

A door chime does not have the spring and screw. Thus, the armature and clapper move only once each time the control switch is operated, and the bell sounds only once. If a second bell is set up for the clapper to strike when it falls away from the first bell, two sounds can occur for each switch operation. Donald W. Novotny

Electric car is an automobile powered by rechargeable batteries. The electric energy stored in the batteries is converted to mechanical power by means of electric motors.

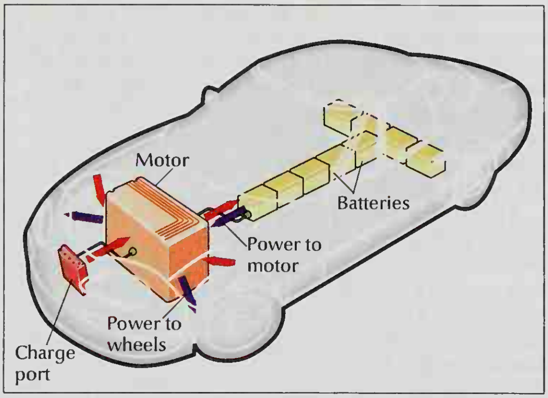
Electric cars have four main advantages over gasoline-powered cars. (1) Their operation produces no exhaust, and so their widespread use could reduce air pollution. (2) They use batteries, and so they do not consume increasingly scarce petroleum resources. (3) Electric cars are quiet, reducing noise in congested areas. (4) Their batteries can be recharged while the owner is at home or at work, and thus the owner can avoid the inconvenience of stopping at a service station to refuel.

The chief disadvantage of electric cars is that they usually can travel no more than 100 miles (160 kilometers) before their batteries must be recharged. The vehicles have even more limited ranges in extreme weather conditions that may require high use of electric power by the heating or cooling system. Many gasoline-powered cars can go more than 300 miles (500 kilometers) before they need refueling. Electric cars also have below-average acceleration. A majority of them have a top speed of less than 80 miles (130 kilometers) per hour. Most electric cars use expensive lead-acid batteries that may have to be replaced several times during the life of the vehicle. Some newer vehicles use nickel metal-hydride batteries, which cost more but can increase the range that can be driven on a single charge.

Another problem with electric cars is that the power required to recharge their batteries is generated at the same plants that provide electric power for cities and towns. If electric cars were used extensively, the capacity of these facilities would have to be greatly increased. The increased capacity would contribute to pollution in areas near plants that burn coal or natural gas, as even plants with advanced pollution control systems produce some pollutants.

How electric cars work. The electric car is powered by one or more electric motors. In most cases, the motors are coupled directly to the wheels. This system eliminates the need for a transmission. The driver uses an *electronic controller* to control the rate at which energy flows from the batteries to the motor or motors. When the vehicle's brakes are applied, the motor or motors become generators sending electric power back to recharge the batteries. Modern electric cars have many complex electronic parts. But they have fewer mechanical parts than do the gasoline-powered cars.

History. The first electric cars appeared in Europe during the 1880's. They soon became popular in the



WORLD BOOK diagram by Precision Graphics

Power to operate an electric car comes from batteries that run a motor. Power to recharge the batteries (shown by red arrows) may come from the motor, wheels, or an outside charger.

General Motors Corporation

A hybrid electric car, such as this Fuel Cell Electric EV1 by General Motors, uses another power source in addition to batteries. This vehicle uses fuel cells, which produce electrical energy from the chemical reaction between a fuel and oxygen.

United States. Americans drove more *electrics* than gasoline cars during the late 1800's. By the early 1900's, however, gasoline-powered cars had become more powerful, performed better, needed less refueling, and were cheaper to operate than electric cars were. The electric car had almost disappeared by the late 1920's.

In the 1960's, increasing concern about air pollution and dwindling petroleum supplies renewed interest in electric cars. In the 1970's, limited production of electric cars resumed. Sales of electric cars have remained low, however, due to their high purchase price, their limited travel range, and their relatively poor performance. The lack of a battery that is inexpensive, powerful, durable, and lightweight also has helped limit the car's success.

Since the late 1970's, manufacturers have experimented with cars known as *hybrids.* These cars have all the components of the electric cars plus another power source, usually some type of combustion engine. This engine can be used to recharge the batteries and, in some cases, to drive the vehicle. Researchers are working to develop *fuel cells,* devices that convert chemical energy to electrical energy, for use in hybrid vehicles (see **Fuel cell**). William H. Haverdink

Electric chair. See Electrocution.

Electric charge. See Electricity (Electric charge).

Electric circuit is the path followed by an electric current. When current flows in a circuit, electric energy associated with the current can do useful work.

An electric circuit has three basic parts: (1) a *source* of electric energy, such as a battery or generator; (2) an *output device,* such as a motor or lamp; and (3) a *connection* between the source and the output device, such as a wire or cable.

The source converts some type of nonelectric energy into electric energy. For example, an electric generator changes mechanical energy into electric energy. The electric source creates an *electromotive force* (emf) that causes an electric current to flow in the circuit. Emf is measured in units called *volts,* and the current it produces is measured in units called *amperes.* Electric outlets in homes in the United States and Canada supply electric energy at voltages from 110 to 120 volts. But the electric outlet itself is not a source of electric energy. Transmission lines connect the outlet to a generator at an electric power plant, which is the source.

An output device uses the electric energy from the source to do something useful. For example, a lamp provides light and an electric motor produces mechanical motion to operate a vacuum cleaner. The source and output device must be connected so that electric current can flow from the source to the device and back again. The return path is necessary so that an electric charge does not collect at any point in the circuit. A collected charge would oppose the flow of current and keep the circuit from functioning.

Various devices may be added to a circuit to control the current flowing in it. For example, a lamp's circuit may include a switch to turn the lamp on and off easily. When the switch is off, a gap separates the connecting wires so that the current cannot complete its path. A circuit with this kind of gap is called an *open circuit.* A *closed circuit* has no gaps in the path of the current.

Some circuits, including those used in homes, are equipped with a *fuse* or a *circuit breaker.* Either of these devices acts as an automatic switch that opens the circuit if too much current flows through it. Excessive current may overheat the wires and start a fire or damage output devices.

An electric circuit may be simple or complex. A simple circuit may consist of only the three basic circuit parts. Simple circuits are used in such equipment as flashlights and lamps. A complex circuit has hundreds or even thousands of circuit parts. Devices that use complex circuits include computers and television sets.

No matter how many circuit parts a circuit has, all circuits except the simplest can be classified as one of three types: (1) series, (2) parallel, and (3) complex. Almost all electric circuits are complex circuits, which consist of both series and parallel types.

Series circuits use a single path to connect the electric source or sources to the output device or devices. If a series circuit is drawn on paper, a line starting at any circuit part will pass through all the other circuit parts only once before returning to the starting point. For example, the circuit in a two-battery flashlight connects the positive terminal of the first battery to the negative terminal of the second battery. The positive terminal of the second battery touches the center terminal of the

flashlight bulb. If the switch is closed, the outer terminal of the bulb touches the negative terminal of the first battery, completing the circuit and lighting the bulb.

Series circuits may be found chiefly in flashlights, some Christmas tree lights, and other simple equipment. These circuits have limited uses because any change in one circuit part affects all the circuit parts. If one light bulb in a series circuit burns out, all the other bulbs also go out because the burned-out bulb has opened the circuit.

The voltage provided by a group of electric sources connected in series is the sum of their individual voltages. But the same amount of current flows through each source and output device. For example, each battery in a two-battery flashlight supplies $1\frac{1}{2}$ volts, and the two together supply 3 volts. The same amount of current flows through each battery and the bulb. Electric sources are connected in series to provide more voltage than one source alone can produce.

Parallel circuits provide more than one path for current. After current leaves a source, it follows two or more paths before returning to the source. If two identical flashlight bulbs are connected in parallel, current flows from a battery through each lamp individually and then back to the battery. Either bulb may be removed from the circuit without breaking the circuit for the other bulb. When both bulbs are on, each receives half the total current from the battery.

Parallel circuits provide the same voltage for every source and output device in the circuit. For example, two $1\frac{1}{2}$-volt flashlight batteries connected in parallel provide an emf of $1\frac{1}{2}$ volts. Electrical sources are connected in parallel to provide more current than one source can produce. But only sources with the same voltage can be connected in parallel. Otherwise, excess current would flow from one source into the other and be wasted.

All household lights and appliances are connected in parallel because a parallel circuit allows all devices to operate on the same voltage. The voltage does not change if a piece of equipment is added or removed. However, the total current passing through the fuse or circuit breaker may increase or decrease. The total current is the sum of the currents flowing through each piece of equipment.

Circuit mathematics. Electricians and engineers use several mathematical formulas to calculate the current and voltage in each part of a circuit. The most important of these formulas are *Ohm's law* and *Kirchhoff's laws.* They were discovered by two German physicists, Georg S. Ohm and Gustav R. Kirchhoff.

Ohm's law relates the voltage and current in a circuit to the *resistance* of the circuit. Resistance opposes the flow of electricity and consumes power from the circuit by changing electric energy into heat. Electricians measure resistance in units called *ohms.* Ohm's law is expressed in the equation $E = IR$. This law states that the voltage (E) equals the current (I) multiplied by the resistance (R), through which the current flows. For example, if a current of 3 amperes passes through a resistance of 2 ohms, the voltage is 3 amperes $\times$ 2 ohms $=$ 6 volts.

In a series circuit, the total resistance equals the sum of the resistances of each device in the circuit. The addition of devices to a series circuit increases the resistance and thus decreases the total current. But in a parallel circuit, adding devices provides additional paths for the current and decreases the total resistance.

Kirchhoff's first law states that the sum of the currents entering any point in a circuit equals the sum of the currents leaving that point. This law is based on the fact that an electric charge cannot accumulate at any point in a closed circuit. Kirchhoff's second law states that the sum of the changes in voltage around any circuit is zero. In other words, the voltage increases through the sources by the same amount that it decreases through the output devices. For example, starting at the base end of a two-battery flashlight, the emf increases through each battery. It increases by $1\frac{1}{2}$ volts in each, for a total increase of 3 volts. The emf decreases 3 volts going through the bulb. Phillip W. Alley

Related articles in *World Book* include:

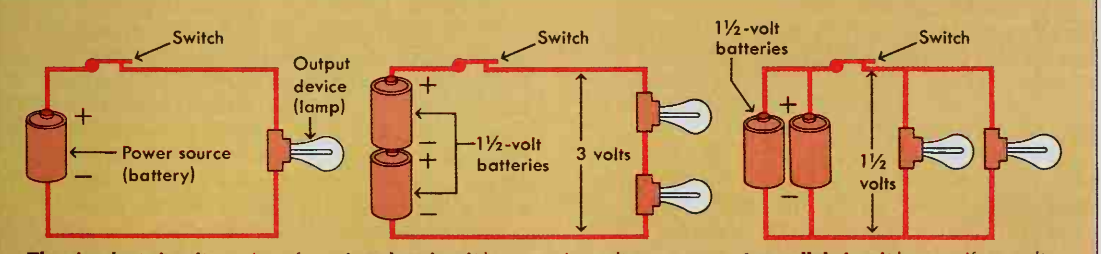
Circuit breaker
Electric current
Electric switch
Electricity
Electronics (Electronic circuits)
Fuse (electricity)
Ground

Electric current is the movement or flow of electric charges. A charge can be either positive or negative. The protons that make up part of the nucleus of every atom have a positive electric charge. The electrons that surround the nucleus have a negative charge. An elec-

Series circuits and parallel circuits

All circuits except the simplest are (1) series, (2) parallel, or (3) *complex* (a combination of the two). Series circuits have their parts connected in one path. Parallel circuits have more than one path.

WORLD BOOK diagram



The simplest circuit consists of a source of electricity, an output device, and connections between them. It may also include a switch.

A series circuit has a varying voltage, depending on the number of its power sources. Two $1\frac{1}{2}$-volt batteries produce 3 volts when connected in series.

A parallel circuit has a uniform voltage, no matter how many power sources. Two $1\frac{1}{2}$-volt batteries connected in parallel produce $1\frac{1}{2}$ volts.

tric current can consist of positive, negative, or both types of charges.

The American statesman and scientist Benjamin Franklin originated the idea that electric current flows from positive to negative. But other scientists later proved that electric current actually flows in the opposite direction— from negative to positive.

Franklin's idea also fails to describe the way electric current flows through metals. Each atom of a metal wire has at least one electron that is not held so closely by the nucleus as the others are. Such loosely held electrons can move freely through the metal. But the nucleus cannot move through the wire. Thus, current flowing through a metal wire consists of free electrons.

Conductors and insulators. Electric current flows most easily through substances called *conductors.* The number of free electrons in a substance determines how well it conducts current. Such metals as aluminum, copper, silver, and gold are good conductors because they have at least one free electron per atom. Some metals, such as lead and tin, are poorer conductors than other metals because they have less than one free electron per atom. Poor conductors resist the flow of electric current more than good conductors do. Resistance changes electric energy into heat. Engineers use units called *ohms* to measure resistance (see **Ohm**).

Substances with no free electrons, such as glass, mica, and rubber, do not normally conduct electric current. They are called *insulators.* Some substances, including germanium and silicon, are neither good conductors nor insulators. They are called *semiconductors* (see **Semiconductor**).

To produce an electric current, some type of nonelectric energy must be converted into an *electromotive force* (emf). For example, a battery creates an emf by changing chemical energy into electrical potential energy. Thus, a battery has a *potential difference* (difference in potential energy) between its ends that causes electrons to flow in a conductor. Emf is measured in units called *volts.* An emf of one volt, when connected to a conductor with a resistance of one ohm, causes 6,241,500,000,000,000,000 electrons to flow past a point in the conductor in one second. This amount of electric current is called one *ampere.* See **Volt; Ampere.**

Direct and alternating current. An electric current is either direct or alternating. Direct current (DC) always flows in the same direction. It is produced by batteries and DC generators. Alternating current (AC) regularly reverses its direction of flow. It is produced by AC generators. Nearly all homes and other buildings use AC.

Each time AC completes two changes of direction, it goes through one *cycle.* The number of cycles per second is called the *frequency* of the AC. Frequency is measured in units called *hertz.* Almost all local power companies in the United States and Canada supply AC with a frequency of 60 hertz.

Direct current operates automobile electrical systems, locomotives, and some types of motors used in industry. Radios, television sets, and other electronic devices use AC, but they also need DC to operate their internal circuits. Devices called *rectifiers* easily change AC into DC. DC is also necessary in order to charge storage batteries.

Alternating current has several advantages over DC. Its major advantage is that power companies can transmit it easily and efficiently. Electric current loses the least amount of energy when traveling at high voltages. But these high voltages are not safe to use in homes. Devices called *transformers* can easily increase or decrease AC voltage.

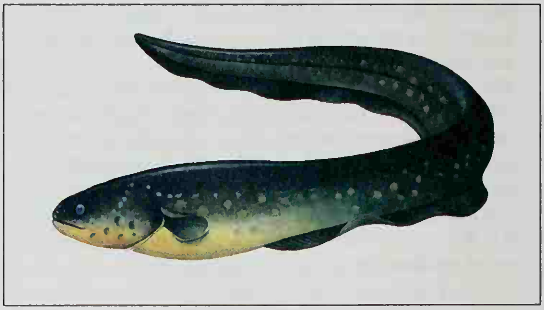
A conductor can carry more than one alternating current at a time. A current consisting of two more individual alternating currents is known as a *polyphase current.* One common kind of polyphase current is *three-phase current,* which consists of three individual alternating currents. Phillip W. Alley

Related articles in *World Book* include:

Battery	Electric power	Insulator, Electric
Electric circuit	Electricity	Transformer
Electric generator		

Electric eel is a long, narrow fish that can produce a strong electric discharge. About 500 species of fish can generate an electric discharge. Of these, the electric eel is the best known and produces the largest electric discharge. It uses its electric discharge to detect underwater objects, to signal other electric eels, and to stun prey. The electric eel looks like other eels, but it is not a true eel. It is related to catfish and carp.

Electric eels live in muddy rivers in northern South America, including the Amazon and the Orinoco. These fish grow to 8 feet (2.4 meters) long and are olive-brown in color. Their long, pointed tail makes up about four-fifths of their total body length. Electric eels have two small fins behind the gills and one long fin on the underside of the body that runs from the tip of the tail almost to the throat.



WORLD BOOK illustration by Colin Newman, Linden Artists Ltd.

The electric eel can produce an electric discharge.

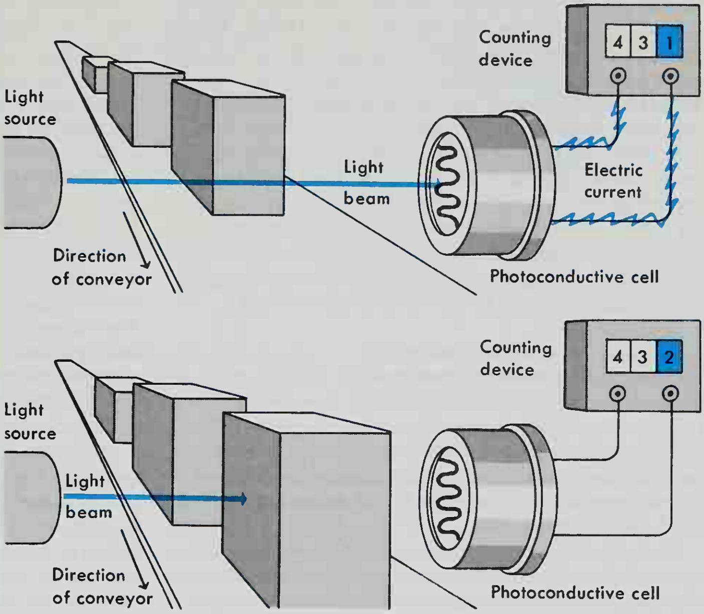
The electric eel's charge is generated by three pairs of electric organs on each side of the body. The largest pair of electric organs runs almost the length of the fish. Under these lie two smaller pairs of electric organs. Each electric organ is made up of thousands of modified muscle cells called *electroplaques.* Electroplaques cannot contract like regular muscle cells can. Each electroplaque gives off a small charge of electric charge when a nerve stimulates it. The charges of all the electroplaques combine to produce 350 to 650 volts, enough to stun a human being or to kill a small fish. The electric eel usually delivers three to five bursts of electric charge each time it discharges. Each burst lasts about $\frac{1}{500}$ of a second.

Photoconductive electric eye

One use for a photoconductive cell, *left,* is to count objects moving on a conveyor belt, *right.* The cell allows an electric current from a counting device to flow through it as long as the light beam from the light source shines on it. When an object on the belt cuts off the beam, the cell stops the flow of current and the counting device adds one number to its total.

WORLD BOOK photo by Ralph Brunke

WORLD BOOK diagram by Tom Morgan



The electric eel eats frogs and smaller fish. Scientists know little about the reproductive habits of the electric eel.

Scientific classification. The electric eel belongs to the family Electrophoridae. It is *Electrophorus electricus.*

John J. Poluhowich

See also **Electric fish.**

Electric eye is an electronic device that either produces a current or allows a current to flow when light shines on it. The strength of the current depends upon the amount of light that falls on the electric eye. When the light stops, so does the current.

Electric eyes can be made more sensitive to light than is the human eye. They can see objects when a person would see only total darkness. Electric eyes respond not only to visible light waves, but also to infrared and ultraviolet waves. Some electric eyes react so rapidly to changes in light that they can "see" bullets in flight.

What electric eyes do. An electric eye can act as a switch to turn another device on or off. For example, an electric eye placed opposite a light across a conveyor belt can count objects on the belt. Each time an object comes between the light and the electric eye, the current flowing from the eye stops. A counting device connected to the eye then adds one number to the total. Electric eyes can turn on street lights or house lights when darkness falls, set off burglar alarms, and perform similar jobs.

Electric eyes can also measure amounts of light. The electric eyes on some cameras measure the light and then properly adjust the lens. Motion-picture projectors use electric eyes to produce sound from special patterns on the film. Some TV equipment uses electric eyes to produce TV pictures.

How electric eyes work. Scientists call electric eyes *photoelectric cells.* There are three basic kinds of photoelectric cells—*phototubes, solar cells,* and *photoconductive cells.*

Phototubes are special vacuum or gas-filled tubes that contain *photosensitive* materials. These materials give off electrons when light strikes them. Every phototube has a *cathode* made of photosensitive material, and an *anode.* When light strikes the cathode, it causes electrons to flow to the anode and creates a current. See **Photomultiplier tube.**

Solar cells, also called *solar batteries* or *photovoltaic cells,* are made of *semiconductor* materials (see **Semiconductor**). When light shines on a solar cell, electrons are given off. They produce a current in a circuit connected to the cell.

Photoconductive cells are made of semiconductor materials, but they do not create an electric current as solar cells do. Instead, when light shines on them, their *resistance* (opposition to the flow of current) decreases. A current can then flow through the photoconductive cells more easily. Paul L. Gerace

Electric field exists in the space around a charged body and can be detected by its effect on another charged body in the field. Every charged body is surrounded by such a field, which can be visualized as imaginary electric lines of force radiating from the object. An electric force acts on other charged bodies that enter the field, causing them to change their motion through the field. Thus, charged bodies exert a force on one another, even when not in physical contact, because of the electric fields that surround them. For example, particles with unlike charges attract one another, and those with like charges repel one another.

The strength of an electric field at any point in the field is directly related to the force it exerts on a small test charge placed at that point. The strength can be calculated using the formula $E = \frac{F}{q}$. In this formula, *E* stands for the strength of the field, *F* for the force, and *q* for the size of the test charge. The direction of an electric field at any point is the same as the direction of the force on a positive test charge at that point. Robert B. Prigo

Electric fish is any of several fishes with special muscles that can generate an electric current. Electric fishes give off strong electric shocks to protect themselves from enemies and to stun or kill prey. They discharge weaker electric currents to detect animals and objects in the muddy waters where they live. The *electric eel* of South America gives the most powerful electric shock. It can produce enough current to stun a human being. An *electric catfish* lives in the rivers of tropical Africa.

John J. Poluhowich

See also **Electric eel; Electric ray.**

Electric generator is a machine that changes mechanical energy into electrical energy. Generators produce almost all the electric power used by people. They furnish electric power that runs machines in factories, provides lighting, and operates home appliances. Generators were once called *dynamos,* a shortened form of the term *dynamoelectric.*

The size of large generators is usually measured in *kilowatts.* One kilowatt equals 1,000 watts. A giant generator can produce more than 1 million kilowatts of electric power. See **Kilowatt.**

There are two main types of generators. *Direct-current (DC) generators* produce electric current that always flows in the same direction. *Alternating-current (AC) generators,* or *alternators,* produce electric current that reverses direction many times every second. Both kinds of generators work on the same scientific principles. But they differ in the ways they are built and used.

How a generator works

Basic principles. A generator does not create energy. It changes mechanical energy into electrical energy. Every generator must be driven by a turbine, a diesel engine, or some other machine that produces mechanical energy. For example, the generator in an automobile is driven by the same engine that runs the car.

Engineers often use the term *prime mover* for the mechanical device that drives a generator. For a generator to produce more electrical energy, this device must supply more mechanical energy. If the prime mover is a steam turbine, for example, more steam must flow through the turbine to produce more electric power.

Generators produce electric power by means of a principle discovered independently by two physicists in the early 1830's—Michael Faraday of England and Joseph Henry of the United States. They found they could produce electric current in a coil of copper wire by moving the coil near a magnet or by moving a magnet near the coil. This process is called *electromagnetic induction.* The *voltage,* or *electromotive force,* of the electric current produced is called an *induced* voltage or *induced* electromotive force. If the wire is part of a closed circuit of wires, the induced voltage causes an electric current to flow through the circuit.

A simple generator may consist of a U-shaped magnet and a single loop of wire. The area around a magnet where its force can be felt is called a *magnetic field.* To help describe a magnetic field, we think of *lines of force* going out from the north pole of a magnet and returning into the magnet at its south pole. The stronger the magnet, the greater the number of lines of force. If you rotate the loop of wire between the poles of the magnet, the two sides of the loop "cut" the lines of force. This *induces* (generates) electric current in the loop.

In the first half of the turn, one side of the loop of wire cuts up through the lines of force. The other side cuts down. This makes the current flow in one direction through the loop. Halfway through the turn, the loop moves parallel to the lines of force. No lines of force are cut and no electric current is generated. In the second half of the turn, the side of the loop that was cutting upward cuts downward through the lines of force. The other side of the loop cuts upward. This makes the electric

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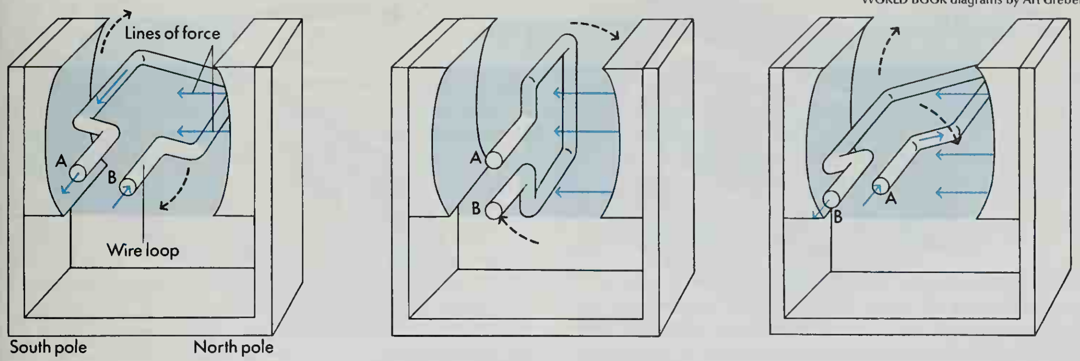
Electric generators at a dam furnish a tremendous amount of electric power. Water turbines drive these generators. Engineers often refer to the mechanical device that drives a generator as a *prime mover.*

How electric current is generated

A simple generator may consist of a U-shaped magnet and a wire loop. Lines of force flow from the north pole of the magnet to the south pole, forming a magnetic field. Rotating the wire between the poles cuts through the lines of force and generates an electric current in the loop.

WORLD BOOK diagrams by Art Grebetz



The current flows from point B to point A through the loop when the wire is rotated clockwise, as shown above.

No electric current is generated in the loop in this diagram because the wire does not cut through the lines of force.

The current reverses as the wire makes the second half of the turn. The current flows from point A to point B.

current induced in the loop flow in a direction opposite to the first half of the turn. At the bottom of the turn, the loop again moves parallel to the lines of force and no electric current is generated. For every complete turn, the voltage and current that are generated travel in one direction half the time, and in the opposite direction the other half of the time. Twice during each turn no current flows. The voltage and current are known as an *alternating voltage* and an *alternating current.* The voltage that a generator produces can be increased by increasing (1) the strength of the magnetic field (number of lines of force), (2) the speed at which the loop rotates, or (3) the number of loops of wire that cut the magnetic field.

One complete revolution of the loop through the lines of force is called a *cycle.* The number of such cycles in a second is called the *frequency* of the voltage or current and is measured in units called *hertz.* One hertz equals one cycle per second. The electric current in most North American homes has a frequency of 60 hertz. In most of the rest of the world, the frequency is 50 hertz.

Electromagnetism. A loop of wire rotated between the poles of a magnet produces another important electromagnetic effect in addition to generating electric current. When the loop of wire carries current, the current produces a magnetic field around the wire. This magnetic field works against the magnetic field of the magnet. It makes the loop harder to turn. The more electric current induced in the loop, the stronger its magnetic field, and the more difficult it is to turn. That is why the prime mover that turns a generator must furnish increased amounts of mechanical energy to increase the output of current by the generator. This same magnetic force in the loop causes the rotation in electric motors. Under proper circumstances, generators can act as motors, and motors as generators. See **Electric motor**.

Parts of a generator. A generator has two main parts: an *armature* and a *field structure.* The armature contains coils of wire in which the current is induced. It acts like the loop of wire in the simple generator. The field structure acts like the simple generator's magnet. It sets up magnetic lines of force. *Electromagnets* create lines of force in most generators (see **Electromagnet**). Some small generators have permanent magnets. These generators are called *magnetos* or *permanent-magnet generators.* The coils for the armature and field structure are usually insulated copper wire wound around iron cores. The iron cores strengthen the magnetic fields.

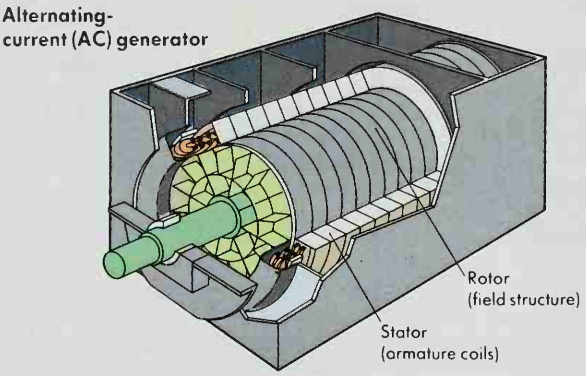
Electric current can be generated either by making the armature cut the lines of force, or by making the lines of force cut past the armature. Because of this, either the armature or the field structure can be the rotating part of a generator. The rotating part is called the *rotor* and the stationary part is known as the *stator.*

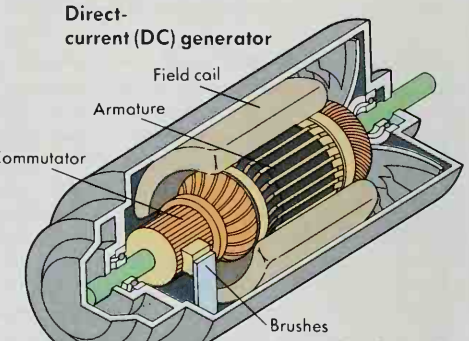
Losses and efficiency of generators. Not all of the mechanical energy used to drive generators is converted to electrical energy. Some of it is converted to heat as a result of friction in the bearings supporting the generator rotor, the resistance of the copper coils to the current, and the action of the magnetic lines of force in the iron cores. Thus, generators must be cooled by blowing air through them, or by running a cooling liquid or gas past the coils, iron cores, and bearings. A generator's *efficiency* refers to its effectiveness in converting mechanical energy to electrical energy. An efficiency of 90 percent means that 90 percent of the input mechanical energy is converted to electrical energy. The remaining 10 percent is converted to heat and must be carried away by the cooling system. Large generators that use conventional electromagnets as a source of magnetic field can have efficiencies as high as 97 percent. Some generators use *superconducting* coils as their source of magnetic field. At low temperatures, superconducting coils offer no resistance to the flow of electric current. As a result, these types of generators reach efficiencies of over 99 percent.

Alternating-current generators

The simple generator we have been describing produces alternating current in a loop of wire. To be an alternating-current generator, it needs some way to send the current it produces to the device that will use it. This is done with the help of *collector rings,* or *slip rings,* and fixed pieces of carbon called *brushes.* Each end of the

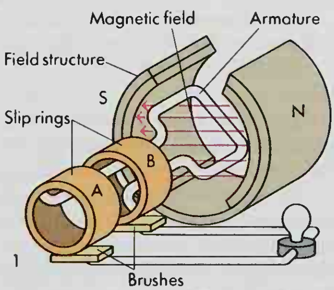
How generators work





WORLD BOOK illustrations by William Graham, adapted from materials provided by General Electric Company

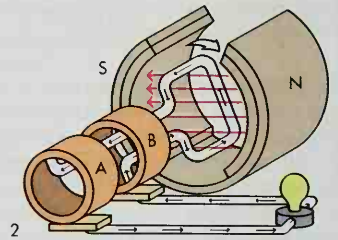
Alternating-current (AC) generator



1

1. A simple alternating-current generator, *left,* has each end of its wire loop, or *armature,* attached to a *slip ring.* A carbon *brush* connected to the outside circuit rests against each of the slip rings.

2. As the armature rotates, *right,* the current moves in the direction of the arrows. The brush at slip ring A conducts the current out of the armature, and the brush at slip ring B brings it back in.



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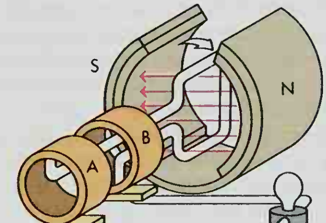
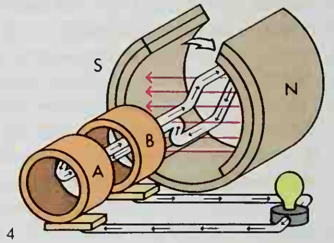


3

3. When the armature rotates parallel to the magnetic field, *left,* no current is generated for a moment. In homes using AC current, we do not notice such stoppages because they happen so quickly.

4. When the armature rotates into the magnetic field again, *right,* the current reverses direction. It now flows out of the armature through slip ring B and back into the armature at slip ring A.



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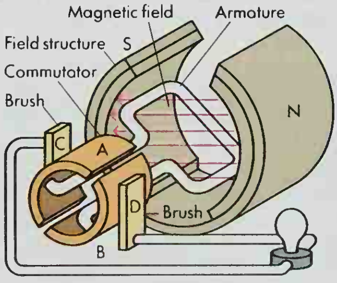
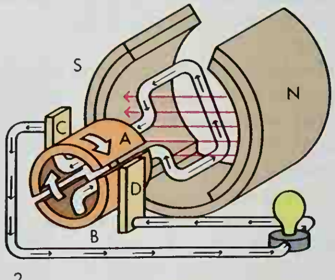
Direct-current (DC) generator



1

1. A simple direct-current generator, *left,* has each end of its wire loop, or *armature,* connected to a *commutator* segment. Carbon *brushes* connected to the outside circuit rest against each segment.

2. As the armature rotates, *right,* brush C rests against commutator segment A and conducts the current out of the armature. Brush D transfers the current back into the armature at segment B.



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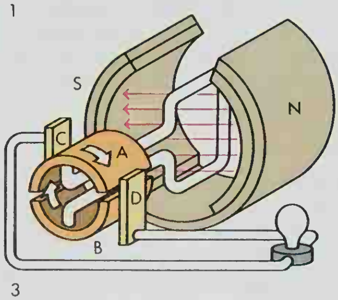
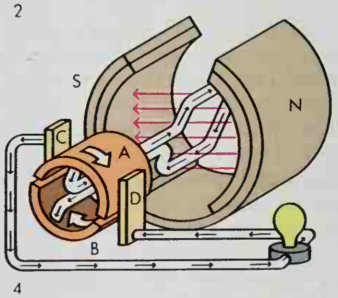


3

3. When the armature rotates parallel to the magnetic field, *left,* no current flows for a moment.

4. In the second half of the turn, *right,* the current in the armature reverses direction and flows out of commutator segment B. But this segment now touches brush C, so the direction of the current in the outside circuit remains the same.



4

loop of wire is connected to a ring. The rings rotate with the loop of wire. A brush rests against each ring. Each brush is connected to a wire leading to the device that will use the electric power. The current produced in the loop of wire flows in and out of the generator through the rings and brushes to the device.

How AC generators work. Practical AC generators differ in several ways from the simple AC generator. They are usually equipped with a small auxiliary generator called an *exciter*. The exciter supplies direct current for the electromagnets used to create the magnetic field in the AC generator. The armature of an AC generator consists of copper wire wound in hundreds of coils around slots cut in an iron core. The electromagnets consist of copper bar wound around iron cores.

In most AC generators, the armature is the stator and the field structure is the rotor. This means that the electromagnets which make up the field structure rotate so the magnetic field sweeps past the armature coils. In these generators, the slip rings are used to carry the direct current from the exciter generator to the electromagnets in the field structure. Outside wires connected to the armature coils take the alternating current induced in the armature directly from the armature. Engineers have found that it is easier to conduct the relatively weak current from the exciter through the slip rings and to take the heavy current produced in the armature directly from the armature. This kind of AC generator is also called a *synchronous generator* because it generates a voltage that has a frequency proportional to, or synchronized with, the speed of the rotor.

The field structure in an AC generator may have only one electromagnet, but it often has two, three, four, or more. This means that the magnetic field produced by the field structure will have two, four, six, eight, or more poles—two for each electromagnet. The generator produces one complete cycle of current each time a pair of poles passes an armature coil, instead of one cycle for each complete revolution of the field structure. Depending on the number of electromagnets, these generators can produce one, two, three, four, or more cycles for each revolution of the field structure or of the armature. A two-pole AC generator must rotate at 3,600 revolutions per minute to generate a 60-hertz current.

Kinds of AC generators. In some AC generators, called *single-phase* generators, the armature has as many sets of coils as the field structure has poles. But most AC generators have three sets of armature coils for each pole. These generators produce three currents of electric power at one time and are called *three-phase* generators. They generate more power for the amount of materials used than do single-phase generators. They also lead to better transmission and use of power.

Uses of AC generators. The main generators in nearly all electric-power plants are AC generators. This is because a simple electromagnetic device called a *transformer* makes it easy to increase or decrease the voltage of alternating current (see **Transformer**). Engineers build AC generators that produce current with only a certain voltage. For many large generators, this voltage is 18,000 or 22,000 volts. By means of a *step-up* transformer, the voltage can be increased as high as 345,000 or 765,000 volts to force the current over long distances. In the area where the current is finally used, a series of *step-down* transformers lowers the voltage to a usable level. Most household appliances, for example, operate on 115 volts. Some office buildings and factories use voltages ranging from 480 to over 4,000.

Nikola Tesla, a Serbian engineer who came to the United States in 1884, developed the first successful *polyphase* AC generators, or generators with more than one phase. He also developed electric motors to use alternating current, and transformer systems for changing the voltage of alternating current. Tesla's inventions made it economically possible to generate current far from the places where the current is used.

Direct-current generators

To change the simple generator into a direct-current generator, two things must be done: (1) the current must be conducted from the rotating loop of wire, and (2) the current must be made to move in only one direction. A device called a *commutator* performs both tasks.

How DC generators work. The commutator rotates with the loop of wire just as the slip rings do with the rotor of an AC generator. Each half of the commutator ring is called a *commutator segment* and is insulated from the other half. Each end of the rotating loop of wire is connected to a commutator segment. Two carbon brushes connected to the outside circuit rest against the rotating commutator. One brush conducts the current out of the generator, and the other brush feeds it in. The commutator is designed so that, no matter how the current in the loop alternates, the commutator segment containing the outward-going current is always against the "out" brush at the proper time. The armature in a large DC generator has many coils of wire and commutator segments. Because of the commutator, engineers have found it necessary to have the armature serve as the rotor and the field structure as the stator.

Kinds of DC generators. In some DC generators, the direct current needed for the electromagnets that make up the field structure comes from an outside source, just as it does in most AC generators. These DC generators are called *separately excited generators*. Many other DC generators use part of the direct current they produce to operate their own electromagnets. These generators are called *self-excited generators*. A self-excited DC generator depends on *residual magnetism*—that is, a small amount of magnetism remains in the electromagnets after the generator is shut off. Without this residual magnetism, it would be impossible to start a self-excited generator once it had stopped.

Direct current needed for a self-excited generator's electromagnets can be drawn from its armature by three connections. These are (1) *shunt,* (2) *series,* and (3) *compound,* a combination of shunt and series connections.

The type of generator used for a certain task depends on the amount of voltage control required. For example, a DC generator used to charge a battery needs only simple voltage control. It might be a shunt generator. A DC generator that supplies electric power for a passenger elevator needs more complicated voltage control. It would be a separately excited generator.

Uses of DC generators. Many DC generators are driven by AC motors in combinations called *motor-generator sets*. This is one way of changing alternating current to direct current. Factories that do electroplating

and those that produce aluminum and chlorine need large amounts of direct current and use DC generators. So do locomotives and ships driven by diesel-electric motors. Because commutators are complex and costly, many DC generators are being replaced by AC generators combined with electronic *rectifiers.* Rectifiers are devices that let current flow in one direction only. They permit use of simpler, more rugged AC generators, even when DC is required. Milton From

Related articles in *World Book* include:

Armature	Electromagnetism	Magnetism
Electric circuit	Electromotive force	Magneto
Electric motor		Tesla, Nikola
Electric power	Faraday, Michael	Transformer
Electricity	Induction, Electric	Turbine
Electromagnet	Lenz's law	

Electric induction. See **Induction, Electric.**

Electric light is a device that uses electric energy to produce visible light. Until electric light became common in the early 1900's, people could see at night only with candles, fires, gaslights, or oil lamps.

The word *lamp* can refer either to a source of electric light, such as a bulb, or to the appliance that holds the source. This article discusses sources of electric light, and it uses the word *lamp* to refer to a light source. There are two main kinds of lamps: (1) incandescent and (2) gaseous-discharge. For information on the uses of electric light, see the *World Book* article on **Lighting.**

Incandescent lamps

Incandescent lamps, one of the most common sources of electric light, may be found in almost every home. Car headlights and flashlight bulbs are also incandescent lamps. The amount of light given off by an incandescent lamp depends on how much power it uses. Most home lamps in the United States and Canada operate on 120 volts and use from 40 to 150 watts of power. Lighting engineers measure the amount of light given off by a lamp in units called *lumens.* An ordinary 100-watt lamp produces about 1,750 lumens. Information on a lamp's packaging includes the number of watts the lamp uses and the number of lumens it produces.

Every incandescent lamp has three basic parts: (1) the filament, (2) the bulb, and (3) the base. The filament produces the light. The bulb and the base help it do its job.

The filament is a thin, coiled wire. When the lamp is turned on, electric current flows through the filament, which connects two heavier wires called *lead wires.* The current must overcome resistance in the filament. In doing so, it heats the filament to more than 4500 °F (2480 °C). The high temperature makes the filament give off light. Lamp manufacturers make filaments from *tungsten,* a strong metal that can withstand high temperatures without melting. The light from a tungsten filament is a mixture of all the colors of light found in sunlight.

Some lamps have more than one filament. These filaments may be turned on individually or together to produce different amounts of light. Thus, a lamp with a 30-watt filament and a 70-watt filament can produce light from 30, 70, or 100 watts of electric power.

The bulb keeps air away from the filament to prevent it from burning up. Most bulbs contain a mixture of approximately 92 percent argon and 8 percent nitrogen. These gases help lengthen the life of the filament.

Manufacturers coat the inside of the bulb with finely powdered white silica to *diffuse* (scatter) light from the filament and to reduce glare. Colored lamps have a coating that filters out all but the desired color of light. Manufacturers produce bulbs in many shapes, including flame-shaped, pear-shaped, round, and tubular.

When incandescent lamps burn out, the cause is usually the slow evaporation and eventual breakage of the filament. Before the filament breaks, currents of gas in the bulb spread the evaporated tungsten over the bulb's inside surface. This tungsten forms a dark deposit on the surface that blocks some of the light.

A tungsten-halogen lamp has a quartz bulb that contains a small amount of a chemical element from the halogen family, usually bromine or iodine. Inside the bulb, the halogen combines with evaporated tungsten and forms a gas. This gas breaks down when it touches the hot filament. The tungsten is redeposited on the filament, and the halogen combines with more evaporated tungsten. Tungsten-halogen lamps provide more light using less power than conventional incandescent lamps, and most last three to four times longer. However, some reach temperatures up to 1200 °F (650 °C) and can cause fires if a lamp is placed near combustible materials.

The base holds a lamp in its fixture and connects the lamp to an electric circuit. The base is attached to the bulb with an adhesive cement.

Gaseous-discharge lamps

Gaseous-discharge lamps, sometimes called *electric-discharge lamps,* produce light by passing electric current through a gas instead of a filament. This process is called an *electric discharge.* In most gaseous-discharge lamps, the gas is enclosed under pressure in a tube or bulb. These lamps include fluorescent lamps, neon lamps, sodium lamps, mercury vapor lamps, and metal halide lamps. In an *arc light,* an electric discharge passes through ordinary air in an unpressurized enclosure.

Fluorescent lamps are widely used in homes, offices, schools, and stores. Lighting engineers install other types of gaseous-discharge lamps in large indoor and outdoor areas. Such areas include factories, highways, parking lots, shopping centers, and sports stadiums. Most neon lamps are used in advertising signs.

Gaseous-discharge lamps cost more than incandescent lamps. But they produce more light per watt and have a longer life, so that their total cost may be less.

Low-pressure gaseous-discharge lamps use argon, neon, and other gases under low pressure to produce light. They include fluorescent lamps, neon lamps, and low-pressure sodium lamps.

Fluorescent lamps. A fluorescent lamp is a glass tube that contains mercury vapor and argon gas under low pressure. Electric current flowing through the tube causes the vaporized mercury to give off ultraviolet energy. The eye cannot see this energy as light. But the inside of the lamp is coated with substances called *phosphors* that give off visible light when struck by the ultraviolet energy. See **Fluorescent lamp.**

Compact fluorescent lamps have replaced many incandescent lamps for home use. They are about the same size as incandescent lamps but may use as little as a fourth of the energy to produce the same light output.

Neon lamps are gas-filled glass tubes that glow when

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An incandescent lamp

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Neon lamps

WORLD BOOK photo by Ralph Brunke

Fluorescent lamps

Photographic Illustrators Corporation (Osram Sylvania)

Metal halide lamps

Sources of electric light include the incandescent and fluorescent lamps used in homes and other buildings, the metal halide lamps that light stadiums, and the neon lamps used to make signs.

an electric discharge takes place in them. Pure neon gas in a clear tube gives off a red-orange light. Other colors result from mixtures of neon and other gases, from colored tubes, or from a combination of these two factors.

Low-pressure sodium lamps consist of two glass tubes, one inside the other. The inner tube contains solid sodium and a mixture of neon and argon gas. When the lamp starts, it emits the red-orange light that is characteristic of neon. But as the sodium heats up, it vaporizes, and the light becomes yellow.

High-pressure gaseous-discharge lamps, also called *high-intensity discharge* (HID) *lamps,* use mercury, metal compounds, or other chemical compounds under high pressure to produce light. Such lamps take several minutes to build up enough pressure to achieve full brightness. They include mercury vapor lamps, metal halide lamps, and high-pressure sodium lamps.

Mercury vapor lamps have two bulbs, one inside the other. The inner bulb, made of quartz, is called the *arc tube.* The outer bulb protects the arc tube. The arc tube contains mercury vapor at a higher pressure than that of a fluorescent lamp and thus allows the vapor lamp to produce visible light without using phosphor coating.

The mercury vapor gives off greenish-blue light as well as ultraviolet rays. A mercury vapor lamp made with clear glass produces no red light, and so red objects appear brown, gray, or black. Mercury vapor lamps with a phosphor coating inside the outer bulb produce light with more colors.

Metal halide lamps contain chemical compounds of a metal and a halogen. These compounds produce more natural color balance than mercury vapor lamps without using phosphors. Metal halide lamps have a long life and a high light output. They make an excellent light source for outdoor uses.

High-pressure sodium lamps resemble mercury vapor lamps. But the arc tube is made of aluminum oxide instead of glass or quartz, and it contains a solid mixture of sodium and mercury, as well as a rare gas. The lamp produces orange-white light, which darkens blues and greens, and turns red to orange. This lamp has a long life and a high light output.

Other sources of electric light

Two sources of electric light, light-emitting diodes and electroluminescent panels, produce dim light directly from electric energy. They do not require a bulb, electric discharge, or filament. But their light is not bright enough to illuminate a room. Some *lasers,* devices that concentrate light waves into tight, powerful beams, use electric energy as a power source.

Light-emitting diodes (LED's) are small chips of solid *semiconductor* material. A semiconductor is a substance that *conducts* (carries) current better than an insulator but not as well as a conductor. LED's give off red, yellow, or green light when electric energy excites their

atoms (see **Light** [Sources of light]). LED's give off very little heat and last almost indefinitely. Groups of LED's are used in some pocket calculators and digital watches to form letters or numbers.

Electroluminescent panels consist of a layer of phosphors between a metal plate and a transparent coating that conducts electric current. The phosphors produce a bluish-green glow when *pulsating current* (current that changes value at intervals) flows through the plate and the coating. Other colors can be achieved by using filters or mixes of different phosphors. Electroluminescent panels use little power. They are used as night lights and on the instrument panels of some aircraft and automobiles.

Lasers have many uses. For example, they are used in communications to transmit signals over long distances in the form of light. Industrial lasers can weld metal or cut ceramics. Doctors can use lasers to perform eye surgery or to remove birthmarks. See **Laser**.

History

During the mid-1800's, a number of inventors tried to create light from electric energy. Several lighting pioneers developed incandescent lamps. These lamps operated with batteries and burned out quickly.

The widespread use of electric light required not only a lamp but also a method of distributing cheap electric power to users. The American inventor Thomas A. Edison developed such a method and won fame as the inventor of the electric light. Edison's incandescent lamp, invented in 1879, had a filament of carbonized thread.

In the early 1890's, Nikola Tesla, an American inventor from Austria-Hungary, demonstrated the earliest versions of fluorescent and neon lighting. During the early 1900's, engineers began to experiment with gaseous-discharge lamps containing mercury. Their work resulted in mercury vapor lamps in the 1930's. Electroluminescence was discovered in 1936. LED's and lasers resulted from research on semiconductor devices in the 1960's.

In the 1970's, researchers developed energy-conserving light sources, such as metal halide lamps and high-pressure sodium discharge lamps. They developed compact fluorescent lamps in the 1980's. William Hand Allen

Related articles in *World Book* include:

Edison, Thomas A.	Fluorescent lamp	Tesla, Nikola
Electric circuit	Laser	Tungsten
Electric current	Neon	Weston, Edward
Flashlight	Sun lamp	

Electric locomotive. See Electric railroad.

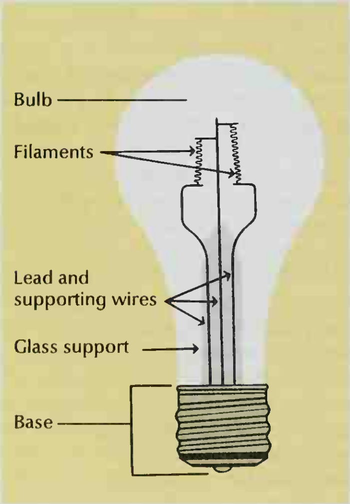
Electric meter is the general name for a number of devices that measure various quantities related to electric energy. Examples of these quantities are voltage, current, power, and *resistance* (opposition to the flow of electric current). A *voltmeter* is a meter that measures voltage. A meter that measures current is called an *ammeter*—named after the unit of current, the ampere. A *wattmeter* measures power in watts, and an *ohmmeter* measures resistance in ohms. A meter that measures two or more electrical quantities is known as a *multimeter*. A multimeter usually has a multiple-position switch that enables the user to select the quantity to measure.

All electric meters have a device that senses either current or voltage. Various internal devices and methods of connection enable a meter to sense one quantity and display a measurement of another quantity—for example, to sense current and display voltage.

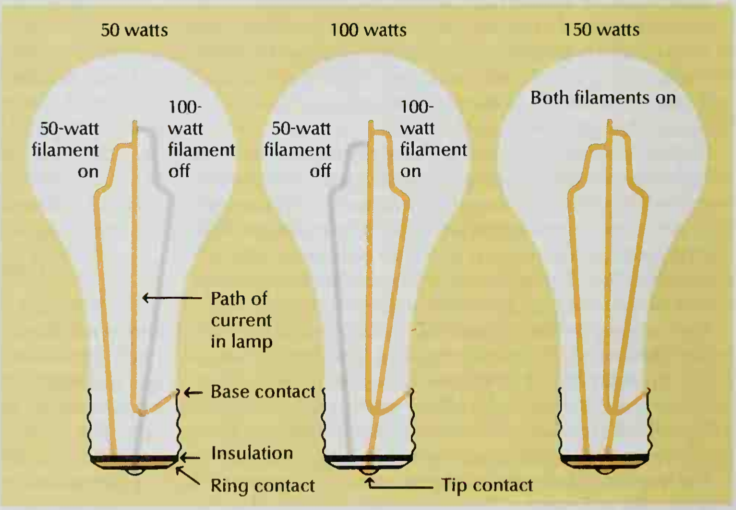
Most meters have two input terminals that are connected by wires to the circuit being measured. The way in which these wires are connected depends on what quantity is being measured.

Electric meters may be either *analog* or *digital*. Analog meters, the older kind, make use of a moving pointer and a scale to display measured values. Digital meters use a numerical readout panel. Digital meters also differ from analog meters in that they have no internal moving parts. In addition, digital meters have much greater sensitivity in measuring than do analog meters.

Analog meters. The main component of an analog



The parts of an incandescent lamp include one or more filaments, an internal support, a bulb, and a base.



WORLD BOOK diagrams

A three-way incandescent lamp uses two filaments to provide three levels of brightness. Separate contacts in the base allow the filaments to be lit individually to give either 50 or 100 watts of light, or lit together to provide 150 watts of light.

electric meter is a coil of wire mounted inside a strong magnet. The coil rotates when an electric current passes through it, and the pointer turns with the coil. The angle to which the coil rotates is proportional to the amount of current flowing. This component can be used by itself to measure small currents. When used in this way, the component is known as a galvanometer.

Analog ammeters and voltmeters use a galvanometer as their main measuring element. Additional components inside the ammeter or voltmeter translate the current or voltage being measured into a current that the galvanometer can measure.

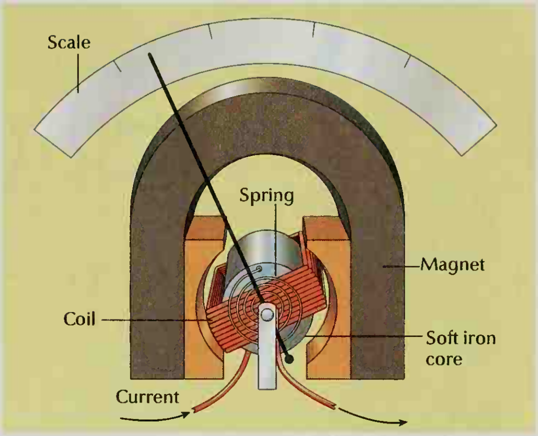
Digital meters. The heart of a digital electric meter is a computer chip called an *analog-to-digital converter.* This device compares the voltage being measured with a series of voltages stored in the chip's memory. The chip quickly finds a voltage that is close to the voltage being measured. The chip then sends to the numerical readout panel a string of electric pulses that represent this voltage. Like an analog multimeter, a digital multimeter has additional components that enable it to measure a wide range of voltage and current.

The time required to make a measurement depends on how precise the measurement must be. Greater precision requires more comparisons and therefore more time. However, a typical converter can make several million comparisons per second.

People generally prefer digital meters over analog meters of comparable cost for two reasons: (1) digital meters are more sensitive, and (2) they draw less current from the circuit being measured. Inexpensive digital multimeters available at retail stores are extremely sensitive. They can measure voltages and currents roughly one-thousandth as strong as those produced by a small watch battery. Meters used in research laboratories can measure quantities a million times smaller than that.

If a meter draws a large amount of current from the circuit being measured, it changes the quantity to be measured—thus producing an inaccurate result. But many people still use analog meters where high accuracy is not essential. In addition, workers often use an analog meter to measure a rapidly changing quantity. The meter is relatively easy to read as the pointer moves up and down the scale; it would be difficult to read the rapidly changing numbers of a digital meter.

Utility meters. The common electric utility meter found in many houses is a type of analog meter. This device measures the amount of electric energy supplied to



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A galvanometer is the simplest analog meter. Current flows through a wire coil mounted on an iron core, creating a magnetic field in and near the core. This field interacts with the field of a magnet, causing the core and an attached pointer to pivot until they are stopped by a counterforce produced by a spring.

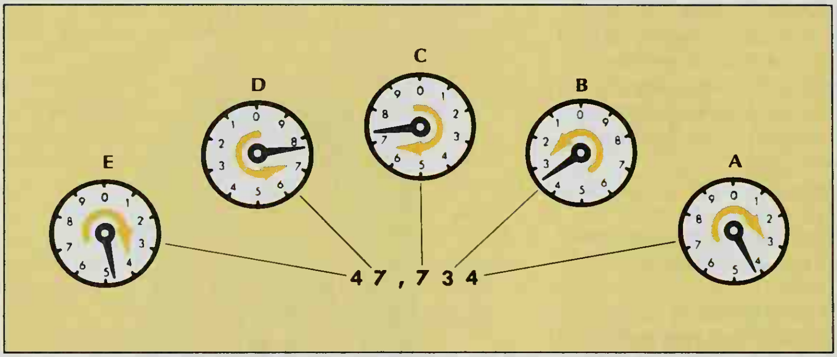
the house. A worker for the local power company reads the meter at regular intervals, and the customer's bill is based on these readings.

The utility meter is actually an electric motor that turns whenever current is flowing through the wires connecting the house to power lines. The rate at which the motor turns increases as the current supplied to the house increases. The shaft of the motor is connected, by a system of gears, to a counter that keeps track of the number of rotations of the shaft. The total number of rotations is proportional to the total amount of electric energy used by the customer. The counter scale and the display—usually four or five dials—therefore can be labeled in units of energy. The energy unit most commonly used by power companies is the *kilowatt-hour.* A kilowatt-hour is 1,000 watt-hours. A 100-watt light bulb left on for 10 hours will use 1 kilowatt-hour of energy.

History. Hans Christian Oersted, a Danish physicist, investigated the effect of electric currents on a magnetic needle in 1820. Also in 1820, Johann Salomo Christoph Schweigger, a German physicist, built the first simple galvanometer. In 1882, Jacques Arsène d'Arsonval, a French medical researcher, greatly improved the performance of the galvanometer. The d'Arsonval galva-

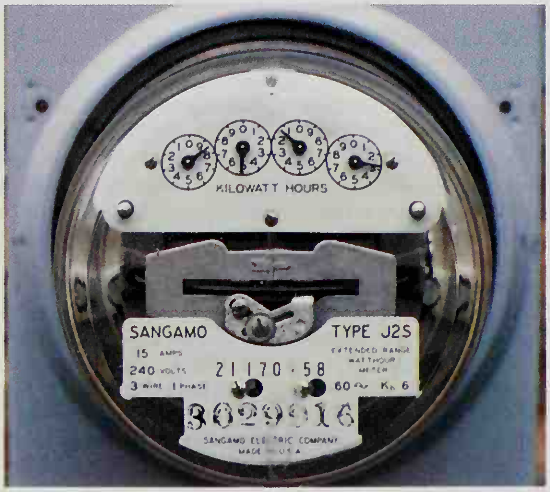
Keithley Instruments

A digital multimeter can measure voltage or current in an electric circuit. The user connects two wires to the circuit. Contacts at the other ends of the wires plug into the front of the multimeter. The multimeter shown can also measure resistance.



Utility-meter dials are read from right to left in units of ones, tens, hundreds, thousands, and ten thousands. The pointer of dial A must make a complete revolution for dial B's pointer to move ahead one unit, and so on. Some meters have four dials instead of five.

WORLD BOOK diagram



WORLD BOOK photo by Ralph Brunke

A utility meter measures in kilowatt-hours the amount of electric power used by customers of electric utility companies. The device is sealed tightly inside a protective glass case.

nometer, the most common type of galvanometer, is named after him.

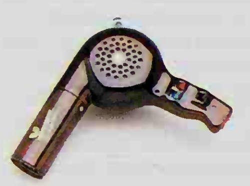
The American Oliver B. Shallenberger, then an electrical engineer with Westinghouse Electric Manufacturing Company, developed the first successful electric meter in 1888. In 1895, he patented an electric meter that became the basis for the electric utility meters used in most homes today. Milton L. From

See also **Weston, Edward.**

Electric motor is a machine that changes electric energy into mechanical power to do work. Electric motors are used to operate a variety of machines and machinery. Washing machines, air conditioners, and vacuum cleaners include electric motors, as do hairdryers, sewing machines, and power drills and saws. Various kinds of motors power machine tools, robots, and other equipment to keep factories running smoothly.

The size and capacity of electric motors vary widely. An electric motor may be a tiny device that functions inside a wrist watch or a huge engine that powers a heavy locomotive. Blenders and most other kitchen appliances use small motors because they need just a little power. Trains require larger and more complex motors because the motor must accomplish a great deal of work within a short time.

There are two general types of electric motors, based on the type of electric current they use. They are (1) alternating current (AC) motors and (2) direct current (DC) motors. Alternating current usually reverses the direction of its flow 60 times per second. Alternating current is available from electrical outlets in homes, and so AC motors are commonly used in household appliances.



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Hairdryer

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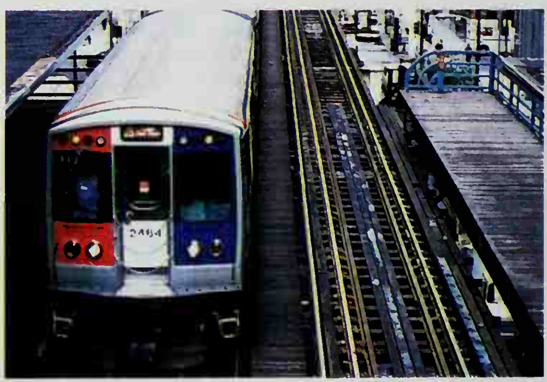
Power drill



WORLD BOOK photo by Ralph Brunke

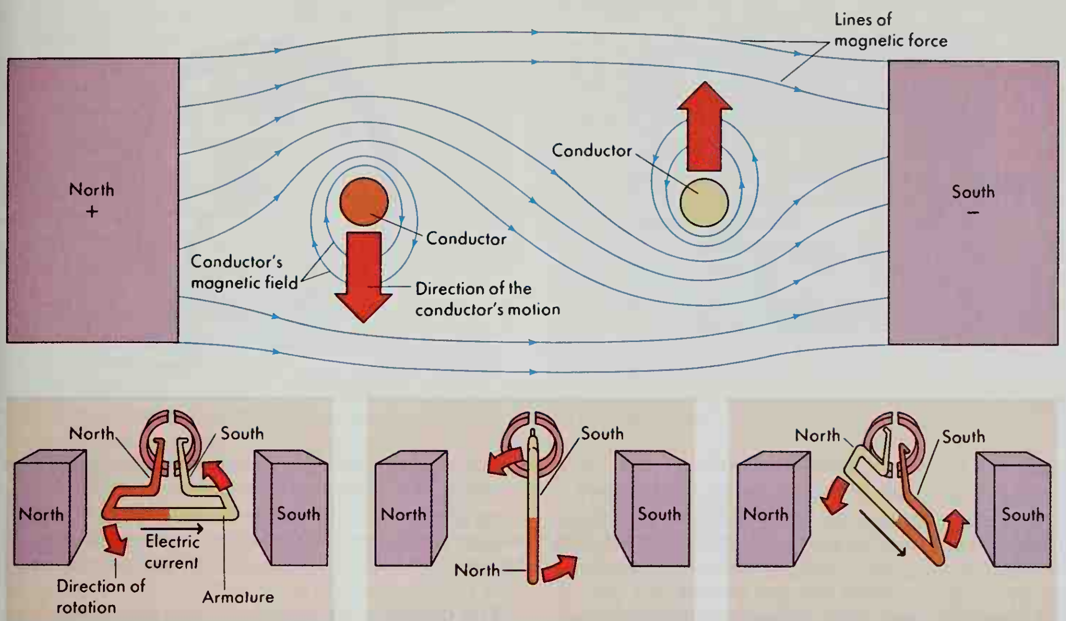
Commuter train

Electric motors vary in size, capacity, and complexity. Small, simple motors power such devices as hairdryers and power drills, but large, complex ones are needed for electric trains.

How an electric motor works

An electric motor basically consists of a stationary magnet and a moving conductor. Lines of force between the poles of the magnet form a permanent magnetic field. When an electric current passes through the conductor, the conductor becomes an electromagnet and produces another magnetic field. The two magnetic fields strengthen each other and push against the conductor.

WORLD BOOK diagrams by William Graham



Rotation begins because the north poles of the *armature* (conductor) and the fixed magnet repel each other, as do their south poles.

Rotation continues as the armature passes the gap in the split rings. The opposite poles of the armature and the fixed magnet attract each other.

The current is reversed, as are the poles on the armature, after the armature passes the gap in the split ring. Rotation can then continue.

Direct current flows in only one direction. Its chief source is a battery. DC motors are commonly used to run machinery in factories. They are also used as starters for gasoline engines. See **Electric current**.

Electric motors depend on electromagnets to produce the force that is necessary for driving a machine or machinery. The machine or machinery driven by an electric motor is known as its *load.* A drive shaft connects the motor to the load.

Basic principles

The operation of an electric motor is based on three main principles: (1) An electric current produces a magnetic field; (2) the direction of a current in an electromagnet determines the location of the magnet's poles; and (3) magnetic poles attract or repel each other.

When an electric current passes through a wire, it produces a magnetic field around the wire. If the wire is wound in a coil around a metal rod, the magnetic field around the wire becomes strengthened and the rod becomes magnetized. This arrangement of rod and wire coil is a simple electromagnet, with its two ends serving as north and south poles. See **Electromagnet**.

The *right-hand rule* is one way of showing the relationship between the direction of the current and the magnetic poles. Hold a coil of wire in your right hand. Supposing the coil is an electromagnet, wrap your fingers around it so that they point in the direction of the current. Your thumb then points toward the electromagnet's north pole. This method works only when a current flows from a positive terminal to a negative one.

Like poles, such as two north poles, repel each other. Unlike poles attract each other. If a bar magnet is suspended between the ends of a horseshoe magnet, it will rotate until its north pole is opposite the horseshoe magnet's south pole. The bar magnet's south pole will be opposite the horseshoe magnet's north pole.

Parts of an electric motor

An electric motor consists chiefly of a rotating electrical conductor situated between the north and south poles of a stationary magnet. The conductor is known as the *armature,* and the stationary magnet called the *field structure.* A *commutator* is also an essential part of many electric motors—especially DC motors.

The field structure establishes a constant magnetic field in the motor. The magnetic field consists of *lines of force* that exist between the poles of the stationary magnet. In a small, simple DC motor, the field structure consists of a permanent magnet called a *field magnet.* In some larger or more complex motors, the field structure is made up of one or more electromagnets that are fed electricity from an outside power source. Such electromagnets are known as *field coils.*

The armature, which is usually cylindrical in shape, becomes an electromagnet when a current passes

Parts of a direct current (DC) motor

A DC motor's most common source of power is a battery. Because direct current travels in only one direction, DC motors rely on commutators with split rings to reverse the flow of the current. The commutator also helps transmit the current between the power source and the armature.

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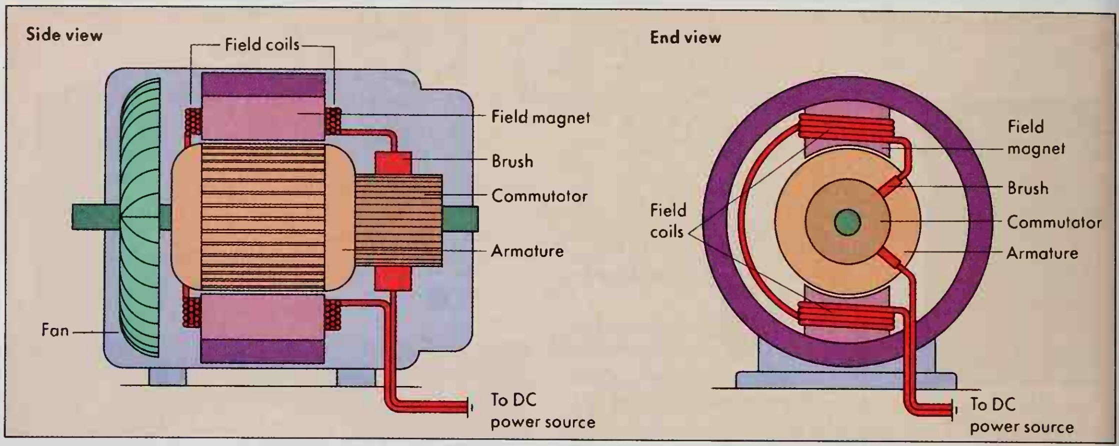


through it. It is connected to a drive shaft so that it can drive a load. In a small, simple DC motor, the armature rotates between the poles of the field magnet until its north pole is opposite the south pole of the magnet. The direction of the current is then reversed to change the north pole of the armature into a south pole. The two south poles repel each other, causing the armature to make another half turn. When the armature's two poles are next to opposite poles of the field magnet once more, the direction of the current is again changed.

Each time the direction of the current is reversed, the armature rotates a half turn. The armature would stop moving if the direction of the current were not reversed. When the armature turns, it cuts the lines of magnetic force created by the field structure. Cutting the magnetic field produces a voltage in the opposite direction of the driving force. This voltage, called a *counter-electromotive force,* reduces the speed of rotation of the armature, as well as the current it carries. If a motor drives a light load, the armature will spin rapidly and generate a large counter-electromotive force. When the load is increased, the armature rotates more slowly. It cuts fewer lines of magnetic force, thereby decreasing the counter-electromotive force. A motor that carries a heavier load thus operates more efficiently, because it uses less energy to do more work.

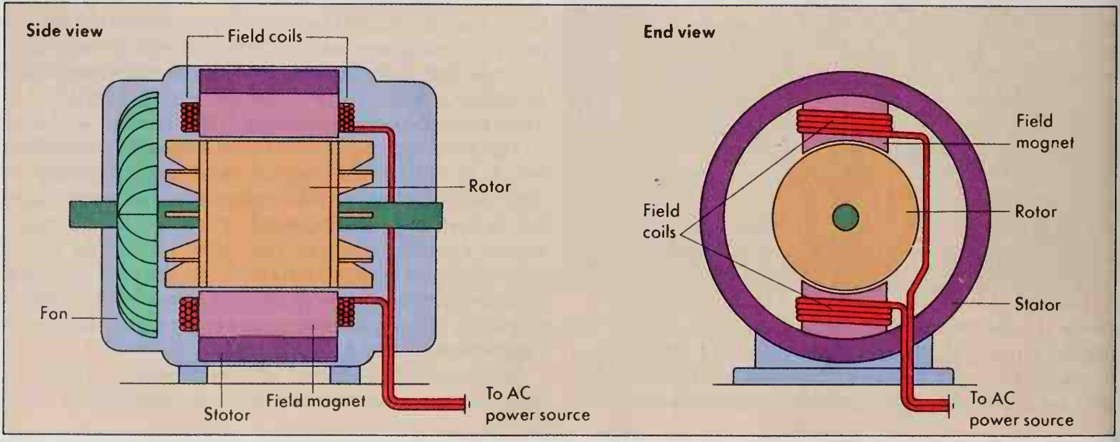
The commutator is used mainly in DC motors. It reverses the direction of the current in the armature and helps transmit the current between the armature and the power source. For a DC motor, the commutator consists of two or more semicircular *split rings,* which are fixed to the drive shaft, next to the armature. Each end of the armature coil is attached to a different ring.

The electric current from the external power source is conducted to the commutator by a small block called a *brush.* Another brush, located on the other side of the commutator, carries the current back to the power source. When one of the rings comes into contact with the first brush, it picks up the electric current from the brush and sends it through the armature. When the

Parts of an alternating current (AC) motor

Most AC motors receive power from electrical outlets. Alternating current reverses the direction of its flow on its own. In AC motors, the rotating conductor is often called the *rotor.* The stationary part, including the field magnet and field coils, is sometimes referred to as the *stator.*

WORLD BOOK diagrams by William Graham



magnetic poles thereby created in the armature are next to like poles of the field magnet, the armature rotates a half turn, past one of the gaps separating the rings. The second ring of the commutator then comes into contact with the first brush and becomes the carrier of the electric current to the armature. In this way, the direction of the current has been reversed, as has the location of the poles in the armature. Like poles of the field magnet and the armature are once again opposite each other, and the armature continues to turn.

Most AC motors do not have commutators because alternating current reverses its direction independently. In AC motors that do have commutators, the commutator simply conducts the current from the external power source to the moving part of the motor and back. It consists of a round *slip ring* instead of split rings.

Kinds of electric motors

DC motors require commutators to reverse the direction of the current. There are three main kinds of DC motors—*series, shunt,* and *compound* motors. They differ from one another chiefly in the circuit arrangement between the armature and the field structure.

In a series motor, the armature and the field magnet are connected electrically *in series.* The current flows through the field magnet and then the armature. As the current flows through the structures in this order, it increases the strength of the magnets. A series motor can start quickly, even with a heavy load. However, such a load will decrease the motor's speed.

In a shunt motor, the magnet and the armature are connected *in parallel.* One part of the current goes through the magnet while the other part passes through the armature. A fine wire is wound around the field magnet many times in order to increase the magnetism. Constructing the field magnet in this way also creates further resistance to the current. The strength of the current and the level of magnetism therefore depend on the resistance of the wire rather than the load on the motor. A shunt motor will run at an even speed regardless of the load. However, if the load is too heavy, the motor will have problems starting.

A compound motor has two field magnets connected to the armature—one in series, the other in parallel. Compound motors have the benefits of both the series and the shunt motor. They can start easily with a heavy load and maintain a relatively constant speed, even if the load is suddenly increased.

AC motors are easy to build and convenient to use. They do not require commutators, and most of them operate on current provided by electrical outlets in households. In an AC motor, the moving part is often called the *rotor,* and the stationary part is frequently known as the *stator.* The most common AC motors include *induction* motors and *synchronous* motors.

The rotor of an induction motor consists of a cylindrical iron core with slots along its length. Copper bars fit into the slots and are fastened to a thick copper ring at each end. The rotor has no direct connection to the external source of electricity. The alternating current flows around the field coils in the stator and produces a rotating magnetic field. This field *induces* (creates) an electric current in the rotor, resulting in another magnetic field. The magnetic field from the rotor interacts with the magnetic field from the stator, causing the rotor to turn.

The stator in a synchronous motor also produces a rotating magnetic field. But the rotor receives current directly from the power source instead of relying on the magnetic field from the stator to induce an electric current. The rotor moves at a fixed speed in step with the rotating field of the stator. The speed is proportional to the frequency with which the alternating current supplied to the stator reverses. Because this frequency is usually fixed, synchronous motors, like shunt and compound DC motors, maintain a consistent speed, even with a changing load. They also use less energy. These motors are ideal for clocks and telescopes, which require precise timing and smooth turning.

Universal motors are built to operate on either DC or AC electricity. A universal motor uses a commutator, and its basic construction resembles the design of a DC series motor. On DC, it performs like a series motor. If AC is used, the magnetic poles of the armature and the field coils reverse with the frequency of the current. Universal motors are popular in many appliances because of their flexibility.

History

The development of electric motors began in the 1800's with the discovery of electromagnets. In 1820, a Danish physicist named Hans Christian Oersted discovered that a wire conducting an electric current produces a surrounding magnetic field. During the 1820's, a number of other scientists found ways of creating stronger and more practical electromagnets. In 1825, William Sturgeon, an English electrician, wrapped a conductor around an iron bar to produce a stronger electromagnet. In the late 1820's, the American physicist Joseph Henry showed that an even more powerful electromagnet could be made by wrapping several layers of insulated wire around a piece of iron. Also in the 1820's, the French mathematician and physicist André Marie Ampère developed mathematical theories describing the behavior of electric currents and magnets.

In 1831, the English chemist and physicist Michael Faraday demonstrated that moving a coil of wire through a magnetic field causes a current to flow through the coil. This knowledge of electromagnetic induction led to the invention of electric generators and other devices. In 1832, Ampère's instrument maker, the Frenchman Hippolyte Pixii, devised a split-ring commutator that received electricity from a DC generator.

In 1873, the first commercially successful DC motor was demonstrated in Vienna at an exhibition by Zénobe Théophile Gramme, a Belgian electrical engineer. Gramme also introduced an armature that improved the efficiency of early electric motors and generators.

In 1888, a Serbian-born engineer named Nikola Tesla invented the AC motor. Tesla designed models for induction and synchronous motors. In the early 1900's, scientists and engineers developed more advanced electric motors, including universal motors. Thomas T. Liao

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Coal-burning electric power plant

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Distribution substation

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Household that uses electric power

An electric power system begins with power plants, which produce large amounts of electric power. Wires carry high-voltage electric current from the power plants to substations, where the voltage is reduced. The current is then distributed to homes, offices, businesses, and factories.

Electric power

Electric power is the use of electric energy to do work. It lights, heats, and cools many homes. Electric power also runs television sets, refrigerators, vacuum cleaners, and many other home appliances. Electric power operates machinery in factories. Escalators, elevators, and computers and other business machines in stores and offices use electric power. Electric power drives many trains and subway systems. On farms, electric machinery performs such tasks as pumping water, milking cows, and drying hay.

Huge electric generators in power plants produce almost all the world's electric power. The majority of these plants burn coal, oil, or natural gas to run the generators. Most other plants drive the generators by means of nuclear energy or the force of falling water. Wires carry the electric current from power plants to the cities or other areas where it is needed. The electric power is then distributed to individual consumers.

Electric power is measured in units called *watts.* For example, it takes 100 watts of electric power to operate a 100-watt light bulb. Ten 100-watt bulbs require 1,000 watts, or 1 *kilowatt.* The amount of energy used is expressed in *kilowatt-hours.* A kilowatt-hour equals the amount of work done by 1 kilowatt in one hour. If you burn ten 100-watt bulbs for one hour or one 100-watt bulb for 10 hours, you use 1 kilowatt-hour of electric energy.

The world's electric power plants can produce more than 3 billion kilowatts of electric power at any given time. The United States leads all other countries in generating capacity. American power plants can generate nearly 800 million kilowatts. Canadian plants can produce more than 100 million kilowatts.

Karen N. Miu, the contributor of this article, is Assistant Professor of Electrical Engineering at Drexel University.

Sources of electric power

Large electric power plants supply nearly all the electric power that people use. The power plants first harness the energy of steam or flowing water to turn the shaft of a device called a *turbine.* The turning shaft drives an electric generator, which converts the shaft's mechanical energy into electric power.

An electric generator has a stationary part called a *stator* and a rotating part called a *rotor.* In the huge electric generators used in power plants, the stator consists of hundreds of windings of wire. The rotor is a large electromagnet that receives electric power from a small separate generator called an *exciter.* An external source of mechanical energy, such as a turbine, turns the rotor. The turning of the rotor creates a magnetic field that turns along with the rotor. As this field rotates, it produces a voltage in the wire windings of the stator that causes a flow of electric current. See **Electric generator.**

The major types of electric power plants are (1) fossil-

fueled steam electric power plants, (2) hydroelectric power plants, and (3) nuclear power plants. Various other kinds of power plants produce smaller amounts of electric power.

Fossil-fueled steam electric power plants generate about 63 percent of the world's electric power and about 70 percent of the electric power produced in the United States. Such plants burn coal, oil, or natural gas. These substances are called *fossil fuels* because they developed from the remains of prehistoric plants and animals. The fuel is burned in a *combustion chamber* to produce heat. The heat, in turn, is used to convert water in a boiler to steam. The steam then flows through a set of tubes in a device called a *superheater.* Hot combustion gases surround the steam-filled tubes in the superheater, increasing the temperature and pressure of the steam in the tubes.

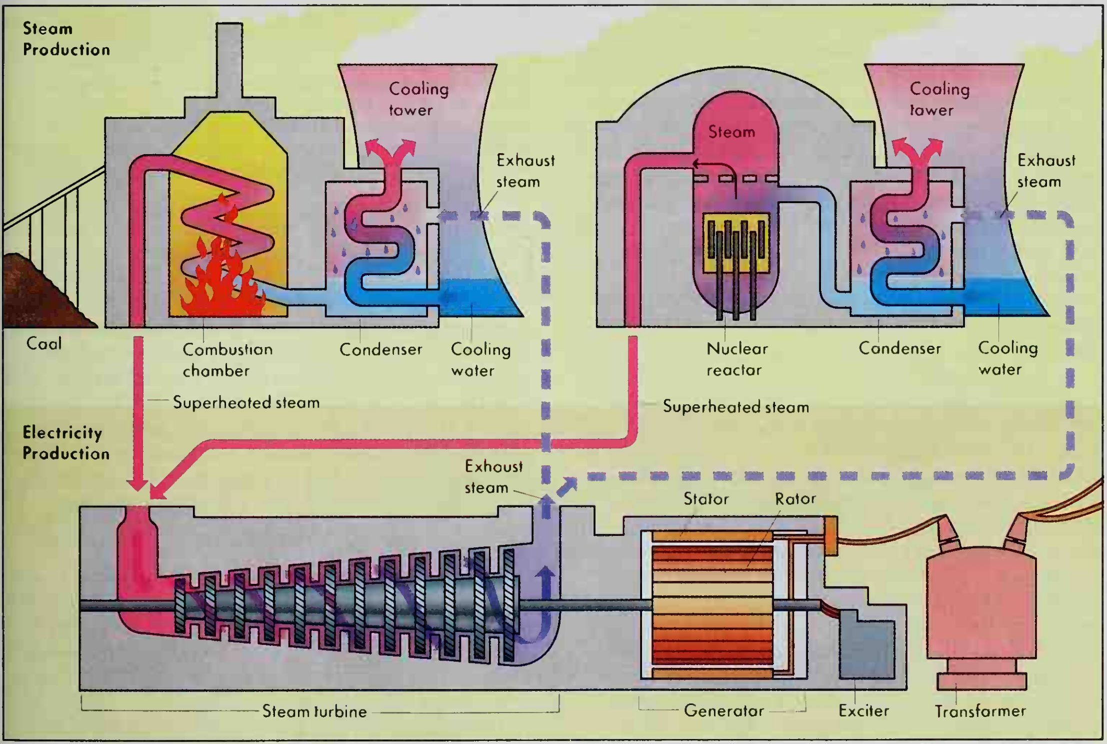
The superheated, high-pressure steam is used to drive a huge steam turbine. A steam turbine has a series of wheels, each with many fanlike blades, mounted on a shaft. As the steam rushes through the turbine, it pushes against the blades, causing both the wheels and the turbine shaft to spin. The spinning shaft turns the rotor of the electric generator, thereby producing electric power. See **Turbine** (Steam turbines).

After the steam has passed through the turbine, it enters a *condenser.* In the condenser, the steam passes around pipes carrying cool water. The water in the pipes absorbs heat from the steam. As the steam cools, it *condenses* into water. This water is then pumped back to the boiler to be turned into steam again.

At many power plants, the water in the condenser pipes, which has absorbed heat from the steam, is pumped to a *spray pond* or a *cooling tower* to be cooled. At a spray pond, the water is sent through nozzles that form a spray of droplets. The spray increases the surface area of the water that is exposed to the air, quickly cooling the water. A cooling tower has a series of decks. The water spills down from one deck to another, cooling as it comes into contact with the air. The cooled water is recycled through the condenser or discharged into a lake, river, or other body of water.

Fossil-fueled steam electric power plants are efficient and reliable. But they can cause pollution. Some power plants do not use cooling towers or spray ponds. They release heated water into lakes, ponds, rivers, or streams. Such *thermal pollution* may harm plant and animal life in these bodies of water. In many areas, laws limit the discharge of heated water by power plants.

The smoke from burning fossil fuels contains chemicals and tiny particles that cause air pollution if they are released into the atmosphere. Most power plants that



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Steam electric power plants create steam by heating water in a nuclear reactor or in a combustion chamber, where coal, oil, or gas is burned. The steam turns a turbine that runs a generator. The generator has a rotating electromagnet called a *rotor* and a stationary part called a *stator.* A separate generator called an *exciter* powers the rotor, creating a magnetic field that produces an electric charge in the stator. The charge is transmitted as electric current. A transformer boosts the voltage. Exhaust steam passes cool water pipes in a condenser and turns back to water for reheating. The water that has absorbed the steam's heat in the condenser is piped to a cooling tower.

burn these fuels use pollution control equipment to limit the release of pollutants. However, the use of such equipment has not fully eliminated the air pollution created by plants that burn fossil fuels.

Hydroelectric power plants generate about 19 percent of the world's electric power and about 8 percent of the electric power produced in the United States. Such plants convert the energy of falling water into electric energy. A hydroelectric plant uses water that is stored in a reservoir behind a dam. The water flows through a tunnel or pipe to the plant's *water turbine,* or *hydraulic turbine.* As the water rushes through the turbine, it spins the turbine shaft, which drives the electric generator. See **Turbine** (Water turbines); **Water power.**

Hydroelectric power plants called *pumped-storage hydroelectric plants* can store energy by operating in reverse. When the demand for electric power is low, such plants can use their generators as motors to turn the turbines. The turbines then function as pumps, raising water to the reservoir. The water can be used at a later time to produce electric power.

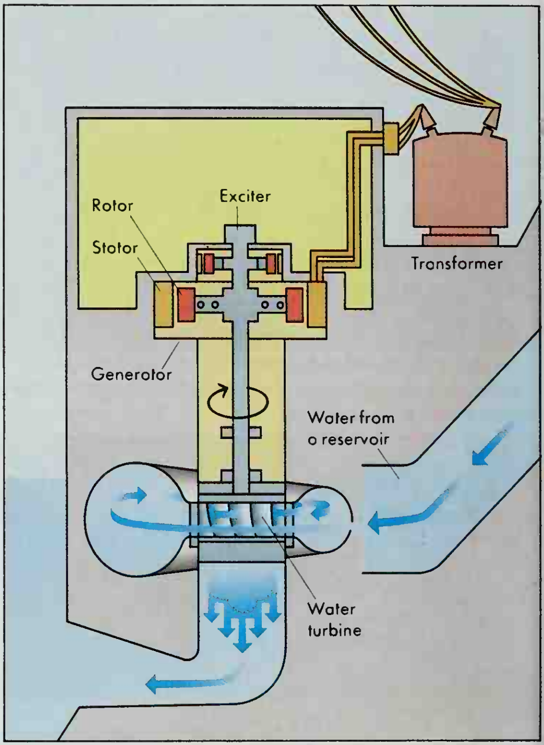
Hydroelectric power plants cost less to operate than fossil-fueled plants and do not pollute the air. The number of hydroelectric power plants is limited, however, by the availability of water power and suitable locations for dams and reservoirs.

Nuclear power plants generate about 17 percent of the world's electric power and about 20 percent of the electric power generated in the United States. Nuclear plants produce electric power in much the same way that fossil-fueled plants do. But instead of a fuel-burning combustion chamber, a nuclear power plant has a device called a *nuclear reactor.* A nuclear reactor produces enormous amounts of heat by *fissioning* (splitting) the nuclei of atoms of a heavy element. Most nuclear plants use the element uranium as the fuel in their reactors.

Heat from the nuclear fission is used to convert water into steam. The steam drives the steam turbine that runs the electric generator. After the steam has left the turbine, it is condensed and recycled through the plant. Many nuclear power plants use cooling towers to cool the water from the condenser pipes.

A nuclear power plant requires much less fuel than a fossil-fueled plant to produce an equal amount of electric power. Nuclear plants also cause much less air pollution. However, they contain dangerous radioactive materials. As a result, the plants must install special safety systems to help prevent and quickly deal with accidents that could cause the release of radiation. Nuclear power plants cost more to build than fossil-fueled plants, partly because of the expense of the safety systems. Nuclear plants also create radioactive wastes that remain hazardous for thousands of years and therefore must be disposed of with extreme caution. See **Nuclear energy.**

Other sources of electric power produce relatively small amounts of electric power. *Geothermal power plants* use steam from the depths of the earth to run turbines that drive electric generators. Some power plants harness wind energy by using windmills to drive electric generators. A number of power plants use the energy of the ocean tides to turn turbines that run generators. Some burn wood or agricultural wastes to drive generators. A few power plants convert the sun's energy into electric power by means of devices called *solar cells.* Producing electric power with solar cells is expensive. However, scientists and engineers are studying ways to improve solar cells to produce large quantities of electric power more economically. See **Solar energy.**



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A hydroelectric power plant uses the force of falling water from a reservoir to turn a turbine that drives a generator. An exciter powers the rotor. As the rotor and its magnetic field turn, an electric charge is created in the stator. A transformer increases the voltage of the current coming from the stator.

A number of electric power plants have gas turbines or diesel engines to drive auxiliary generators. Such generators supply the extra power needed in times of high demand. Diesel engines are also used to drive generators in isolated areas not served by power companies. Many hospitals, factories, and apartment buildings have diesel engines to drive generators in case the distribution of power from power plants is disrupted.

Transmitting and distributing electric power

The electric power generated by power plants is usually transmitted 50 miles (80 kilometers) or more to cities or other areas. From those areas, it is distributed to nearby houses, factories, farms, offices, and other consumers. An electric power distribution system is sometimes called a *power grid.*

Transmission. Most electric current travels from power plants along overhead wires called *transmission lines.* Laying underground or underwater cables generally costs more than stringing overhead wires. Cables are therefore used much less often than overhead wires.

As electric current moves along transmission lines, the lines resist the current flow. The resistance causes the current to lose energy by heating the lines. Power

plants limit energy losses by transmitting electric power at high voltages. As voltage is increased, the amount of current needed to transmit a particular amount of electric power decreases. Because less current flows through the line, less energy is lost due to resistance.

Electric current may be either *direct current* (DC) or *alternating current* (AC). Direct current flows in only one direction. Alternating current reverses direction many times each second. It is easier to boost the voltage of alternating current than that of direct current. AC is therefore easier to transmit than DC. For this reason, electric power plants generate alternating current.

The typical power plant generator can produce about 1 million kilowatts of electric power at up to 22,000 volts. Devices called *step-up transformers* then boost this voltage as high as 765,000 volts for transmission.

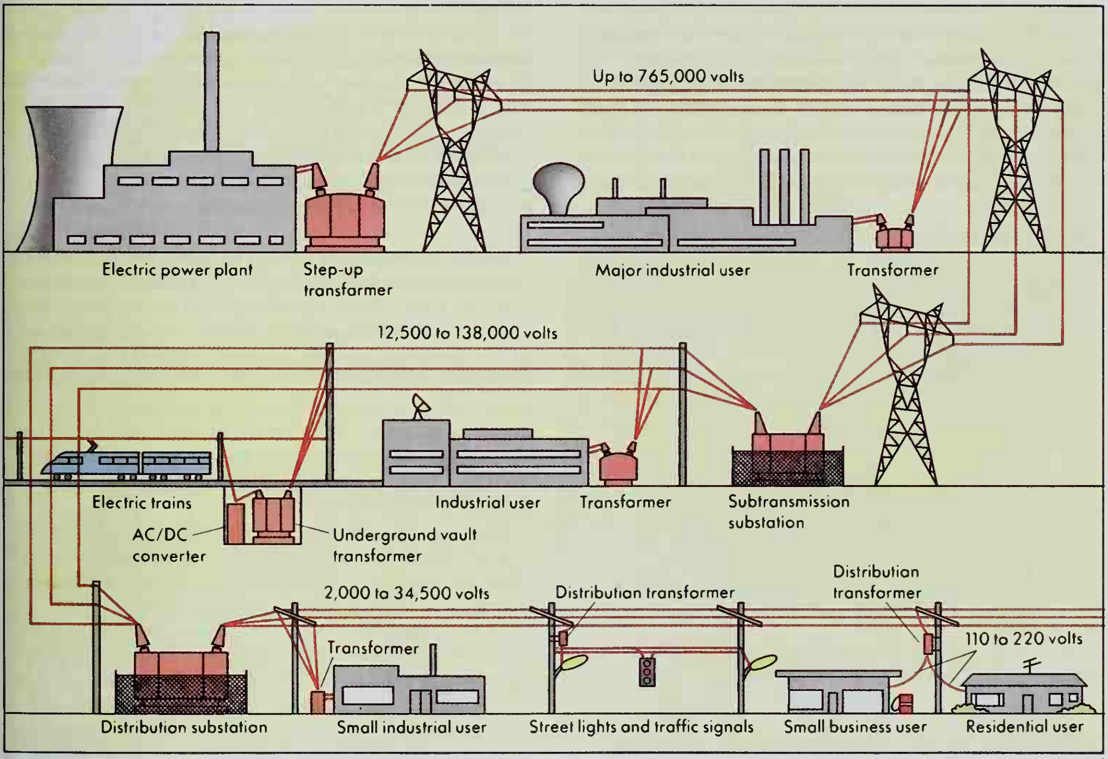
Distribution. Some large industries require high-voltage current and receive it directly from transmission lines. But high-voltages are unsafe in homes, offices, and most factories. The voltage must therefore be decreased before electric power is distributed to them.

High-voltage current is carried by the transmission lines to *subtransmission substations* near the area where the power will be used. These substations have devices called *step-down transformers* that reduce the voltage to 12,500 to 138,000 volts. The voltage is then further reduced at *distribution substations* to 2,000 to 34,500 volts. *Distribution lines* may carry this medium-voltage current directly to commercial, industrial, or institutional users. Distribution lines also carry electric power to *distribution transformers* on poles, on the ground, or in underground vaults. Distribution transformers reduce the voltage to the levels needed by most users. Wires from the transformers run to homes, stores, offices, and other users. Nearly all such consumers in the United States and Canada receive power at about 110 or 220 volts.

Providing reliable service. Equipment failures or damage caused by storms or accidents can interrupt local service of electric power. Such interruptions are known as *power blackouts.* Engineers called *load dispatchers* keep track of the flow of current through the transmission network. When a blackout occurs, the load dispatcher may restore service to the affected area by rerouting current along usable lines.

The demand for electric power often varies greatly from hour to hour. For example, sudden, dark storm clouds will increase demand because many lights will be turned on. The load dispatcher forecasts changes in demand and adjusts the generation and transmission of power accordingly. When demand exceeds the generating capacity of a power plant, the load dispatcher may reduce the voltage to prevent a blackout. Such a situation, called a *brownout,* may damage electrical equipment or cause it to operate less efficiently.

The transmission networks of most electric companies are interconnected, forming a power pool. Power



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An electric power distribution system has power lines to carry current and transformers to change its voltage. Step-up transformers boost voltages so that current can be transmitted long distances. Substations and transformers reduce voltages to levels needed by consumers. Some industrial users and transportation systems that require high voltages have their own transformers.

pools enable companies to receive power from one another in an emergency. Computers control the flow of electric current through transmission networks.

The electric power industry

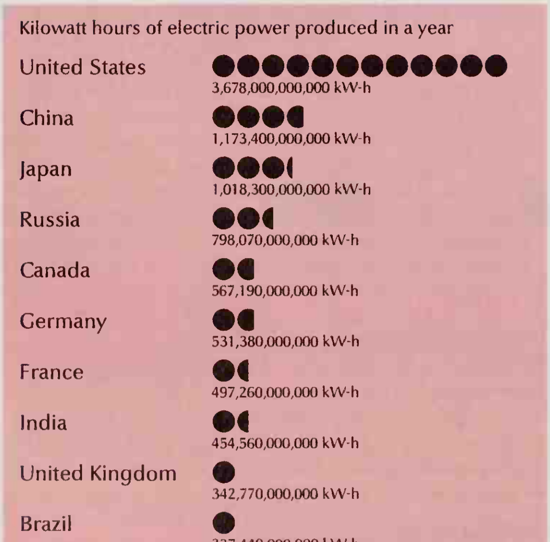
Organizations that generate, transmit, or distribute electric power are called *electric utilities.* In most countries, nearly every electric utility is the sole supplier of electric power in a particular area. Government agencies regulate electric utilities to ensure that they serve the needs of the public. In some countries, the national government owns all electric utilities. In others, stockholders, cooperatives, or local or regional governments may own some electric utilities, and the national government may own others. The United States is the world's leading generator and consumer of electric power.

Some countries can generate more electric power than they need, and they export this excess power. Canada exports electric power to the United States, France exports to the United Kingdom, and many African countries export to neighboring nations.

In the United States, about 850 electric utilities operate more than 3,000 power plants. Stockholders own about 80 of these utilities, including many of the largest. This small group of utilities accounts for about 85 percent of the nation's generating capacity. The remaining utilities are owned by cities, cooperatives, public power districts, or state or federal government organizations. Most cooperatives were established to supply electric power to rural areas not served by other electric utilities. Public power districts consist of several counties that jointly produce and distribute electric power.

Local and state utility commissions usually set the rates that electric utilities charge their customers. Some federal agencies govern the design and licensing of power plants, regulate the interstate sale of electric power, and set and enforce pollution control standards.

Leading electric power producing countries



Figures are for 1999.
Source: U.S. Energy Information Administration.

In 1992, the U.S. government began to take steps to deregulate the electric power industry and to allow electric utilities to compete for customers. Many states now have open competition between electric utilities, which set their own rates.

In Canada, the governments of the various provinces own most major electric utilities. But stockholders own large electric utilities in Alberta and Prince Edward Island. Provincial public utility boards regulate Canada's electric utilities. The federal Atomic Energy Control Board oversees the nuclear energy industry. The National Energy Board controls the export of electric power.

History

Early developments. One of the earliest practical uses of electric power was to light the lamps of lighthouses. In 1858, South Foreland Lighthouse near Dover, England, became the first electric lighthouse. Its generator powered an *arc lamp.* An arc lamp produces bright light by means of an electric arc (see **Electric arc**). Beginning in the 1870's, arc lamps illuminated such places as railroad stations, factories, and public squares in major cities in Europe and the United States.

In 1879, the California Electric Light Company in San Francisco began operating the world's first central power plant that sold electric power to private customers. Also in 1879, the American inventor Thomas A. Edison perfected a lamp that glowed and gave off light when a filament in the lamp was heated by an electric current. Edison's *incandescent* lamp burned much longer than an arc lamp, and it quickly created a growing demand for electric service. In 1882, Edison opened the Pearl Street Station, a steam electric power plant, in New York City. Soon after it opened, the plant was providing direct current to light more than 1,000 incandescent lamps.

Growth of the electric power industry. By the end of the 1800's, there were over 3,600 electric utilities in the United States. However, they did not all provide electric power at the same voltages. Studies conducted by electrical engineers in 1891 resulted in standardization of voltages. Utilities could then form power pools.

By the early 1930's, electric utilities served about two-thirds of the U.S. population. But only about 10 percent of U.S. farms had electric power. President Franklin D. Roosevelt established the Rural Electrification Administration (REA) in 1935 to expand electric service in rural areas. By the early 1990's, nearly all American farms had electric power, and half were served by REA-financed electric power systems. In 1994, the REA was replaced by the Rural Utilities Service.

The first full-scale nuclear power plant began operation in 1956 at Calder Hall in northwestern England. In 1966, the world's first tidal power plant opened on the Rance River near St.-Malo, France.

Electric power today. Power companies must plan carefully for expansion to meet the ever-increasing demand for electric power. However, construction of new plants is costly and takes several years. Many planned nuclear power plants have been canceled because of soaring construction costs as well as safety concerns.

The supply of fossil fuels will eventually run out unless economical substitutes can be developed for them. Many scientists believe that energy from the earth, sun, wind, and oceans can be used more extensively to pro-

duce electric power in the future. Some utilities now use solar, geothermal, tidal, or wind power in addition to regular energy sources to generate electric power.

Electric utilities rely increasingly on computerized control systems. The use of such systems and the widespread interconnection of power lines among electric companies enable the utilities of industrialized countries to provide generally reliable service. Karen N. Miu

Related articles in *World Book* include:

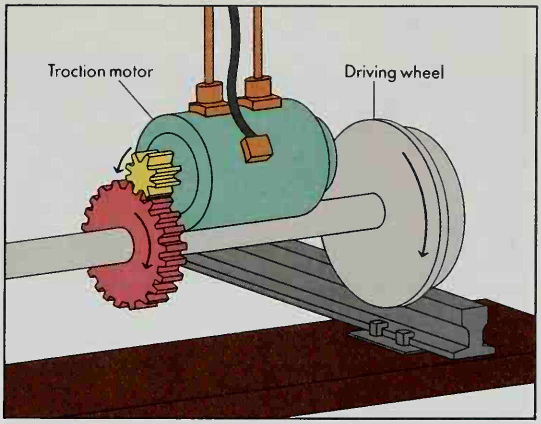
Electric current
Electric generator
Electricity
Energy supply (Sources of energy)
Rural Electrification Administration
Tennessee Valley Authority
Transformer
Turbine
Wind power

Outline

I. Sources of electric power
A. Fossil-fueled steam electric power plants
B. Hydroelectric power plants
C. Nuclear power plants
D. Other sources of electric power
II. Transmitting and distributing electric power
A. Transmission
B. Distribution
C. Providing reliable service
III. The electric power industry
A. In the United States B. In Canada
IV. History

Questions

What is a *brownout?*
How long must you burn one 100-watt light bulb to use 1 kilowatt-hour of electric energy?
What does a *load dispatcher* do?
Why do power plants transmit electric power at high voltages?
What is a *power pool?*
What are the three major types of electric power plants?
Why do power plants generate alternating current?
When and where did the first full-scale nuclear power plant begin operation?
What source of energy do *geothermal power plants* use?
Which type of electric power plant produces most of the world's electric power?



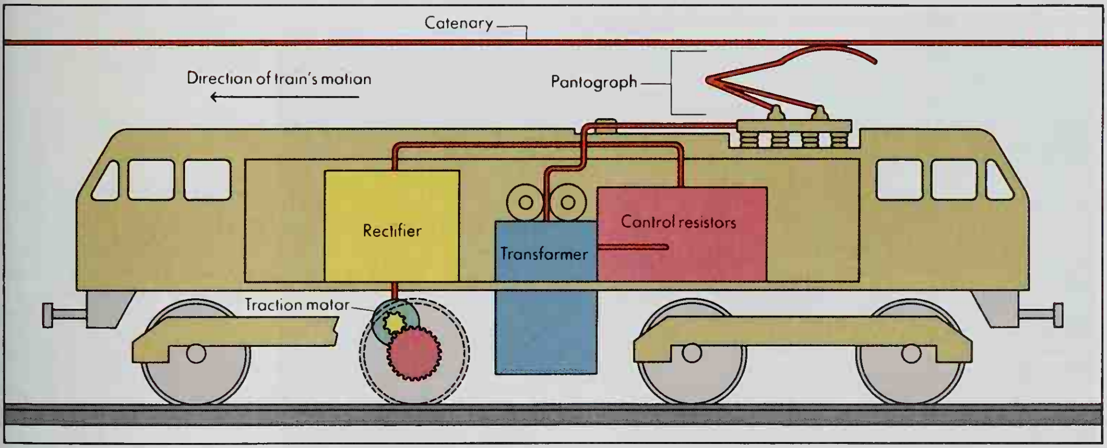
WORLD BOOK illustration by William Graham

The propulsion system of an electric train includes the traction motor and the driving wheel. The traction motor turns the driving wheel, which actually makes the train move.

Electric railroad is an electrically powered railway system. Electrically powered trains include high-speed passenger trains; some freight trains; and the subways, elevated systems, and streetcars found in certain cities. The electric power to run an electric train comes from an external source—a central power plant—rather than from an engine or generator on board the train.

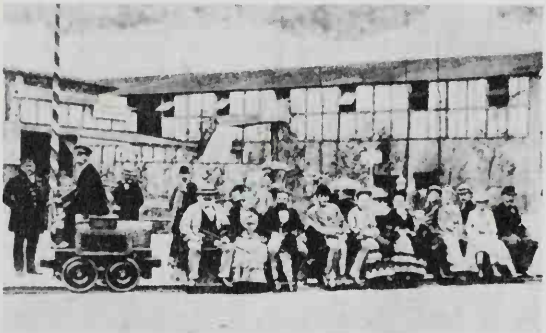
Electric trains have many advantages. They are quieter than other trains and do not produce smoke or exhaust. Coal, gas, oil, nuclear power, or water power can generate electric power for an electric train. In contrast, diesel trains run only on diesel oil. Electric trains also travel faster than any other trains. The world's fastest electric trains are France's TGV *(train a grande vitesse,* or high-speed train) and Japan's *Shinkansen,* or "bullet train." Both have a top speed of 186 miles (300 kilometers) per hour. Engineers are developing faster electric trains called *maglev* (magnetic levitation) trains. German and Japanese models of these trains test from about 280 to 340 miles (450 to 550 kilometers) per hour.

Electric railroads provide *intercity service* (service



WORLD BOOK illustration by William Graham

A typical electric train receives power from a *catenary* (overhead wire) or from an electrified third rail. In the overhead wire system, *shown here,* a pantograph conducts electric current to the transformer. The current eventually arrives at the traction motors, which are part of the train's propulsion system.



Electric Railroad Assn.

The first generator powered electric railroad, *pictured here,* was shown at the Berlin Exhibition of 1879. It included three cars that carried 20 passengers 8 miles (13 kilometers) an hour.

L Levine, Berg & Associates

A commuter train in Washington, D.C., *shown here,* receives its power through an electrified third rail. The electricity for some modern electric trains is provided by an overhead wire.

between cities). These railroads also offer *intra-urban* or *commuter service,* which carries passengers within cities and between cities and their suburbs. Electric railroads are common in many European countries and in Japan. However, in the United States only about 1 percent, or 2,000 miles (3,200 kilometers), of intercity track is electrified.

Kinds of electric railroads. Most intercity electric trains receive power through an overhead wire called a *catenary.* In the overhead wire system, a steel framework connects a car, usually a locomotive, to a catenary. The framework, called a *pantograph,* delivers electric current from the wire to the locomotive's propulsion system. This system includes the *traction motors.* Traction motors power the *driving wheels,* which actually move the locomotive.

Intercity electric trains have one or more locomotives that pull freight or passenger cars. Most electric locomotives weigh between 100 and 200 short tons (90 and 180 metric tons) and provide about 6,000 to 7,000 horsepower (4,500 to 5,200 kilowatts). They can reach speeds of over 150 miles (240 kilometers) per hour.

An electrified third rail delivers electricity to most intra-urban electric trains. Trains using a third rail have metal plates called *shoes.* Two shoes attach to the bottom of a locomotive or railcar. The shoes slide along the third rail, delivering electric current to the car's propulsion system.

Some intra-urban railcars have traction motors, which range from 119 to 282 horsepower (89 to 210 kilowatts). Others are driven by locomotives or by railcars that have traction motors. Intra-urban railcars reach speeds of about 50 to 75 miles (80 to 120 kilometers) per hour.

Unlike most electric trains, a maglev train has little or no contact with a track or wires. Maglev trains have special magnets in the bottom of the cars. The magnets in the cars and electrically charged coils in the *guideway* (track) create a strong magnetic force. This force lifts the cars above the guideway. Separate electric currents in the coils create a shifting magnetic field that propels the train forward. Maglev train systems are in development in many parts of the world. Maglev trains have exceeded 340 miles (550 kilometers) per hour on test tracks.

History. In the early 1800's, the Scottish inventor Robert Davidson built the first full-sized electric locomotive. But the high cost of producing electricity made it too expensive for general use by railroads. The development of the *electric generator* in the mid-1800's made the modern electric railway possible. This device generated a current of high voltage at low cost.

Christian Delemarre, Société Nationale des Chemins de Fer Français

The French TGV (*train à grande vitesse,* or high-speed train) is one of the world's fastest electric trains. The TGV shown here speeds between Paris and Lyon and some Swiss cities at up to 167 miles (269 kilometers) per hour. A newer TGV reaches a speed of about 185 miles (300 kilometers) per hour. The TGV gets its power from an overhead wire.

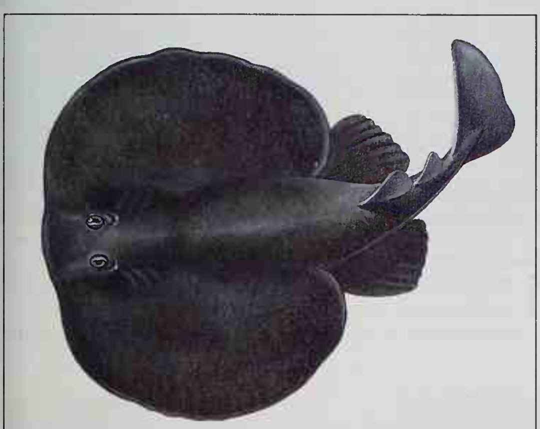
The first commercial electric street railway began operation in Lichterfelde, Germany, in 1881. In 1887, Frank J. Sprague, an American inventor, built the Union Passenger Railway in Richmond, Virginia. This was the first large electric railway system. By the early 1900's, electric elevated trains operated in Chicago, Boston, and New York City. Europe built many electric intercity tracks in the late 1940's. The first high-speed electric train, Japan's *Shinkansen,* began running in 1964. France's TGV began service in 1981. Vernon P. Roan

Related articles in *World Book* include:

Diesel engine	Railroad
Elevated railroad	Streetcar
Locomotive	Subway
Magnetic levitation train	Transit

Electric ray is the name of a group of fish that are able to give off electric charges. They live on the bottom of warm seas. Most electric rays are found in shallow coastal water. However, some live as deep as 1,200 feet (370 meters).

Electric rays have a flat, wide body and a slender, pointed tail with fins. Their colors vary, but most species are dark brown, blue, or gray with spots. Electric rays measure from 6 inches to 7 feet (15 to 215 centimeters) long. A pair of special organs on the upper side of the head allow the fish to give off electric charges. The skin follows the honeycomb shape of the electric organs it covers.



WORLD BOOK illustration by Colin Newman, Bernard Thornton Artists

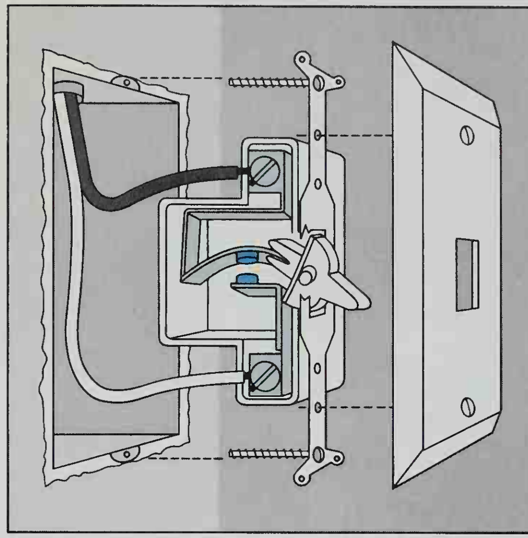
An electric ray has a wide body and a pointed tail.

Electric rays produce electric charges to defend themselves and to stun their prey. They eat shellfish, worms, and other small fish. The shock from a full-grown, healthy ray can stun a human being.

Electric rays are not as active as most other fish. Many cover themselves with sand or mud and remain mainly stationary or swim slowly at the sea bottom. The eggs of most fish hatch outside the female's body, but female electric rays hatch their eggs inside their bodies and so give birth to live young. John D. McEachran

Scientific classification. Electric rays belong to three families: Torpedinidae, Narcinidae, and Narkidae.

Electric shock. See First aid (Restoring breathing); **Shock treatment.**



WORLD BOOK illustration by Zorica Dabich

An electric switch controls the flow of electric current in a circuit. This diagram shows a light switch in the off position. Turning the switch on connects two metal contacts—colored blue above—so that current flows through the circuit.

Electric switch is a device that controls the flow of electric current in a circuit. The most common type of electric switch is the *snap-action toggle switch* used to turn lights on and off. In such a switch, an insulated handle activates a hidden mechanism that completes or breaks the circuit. Turning the switch on connects two metal contacts so that current flows through the circuit. Turning it off separates the contacts and breaks the flow of current.

Electric switches may be classified according to the arrangement of their contacts. The simplest kind, a *single pole, single throw switch,* controls the flow of current along a single path. A *double pole, single throw switch* has two sets of contacts controlled by the same handle. In this way, two circuits can be controlled at the same time. A pair of *single pole, double throw switches* allows a light to be turned on and off from either of two locations. Each switch moves a contact back and forth between two wires. Electric current flows when the contacts in both switches are connected to the same wire. Flipping either of the two switches breaks the circuit by moving one contact to the other wire. Douglas M. Lapp

See also **Circuit breaker; Electric circuit.**

Electric train. See **Electric railroad.**

Electrical engineering. See **Engineering** (The branches of engineering).

Electrical Workers, International Brotherhood of (IBEW), is a labor union affiliated with the American Federation of Labor and Congress of Industrial Organizations and with the Canadian Federation of Labour. It was organized in 1891 in St. Louis, Missouri, as the National Brotherhood of Electrical Workers. In 1899, it opened its membership to Canadians and adopted its present name.

The union's headquarters are in Washington, D.C. For membership, see **Labor movement** (table).

Critically reviewed by the International Brotherhood of Electrical Workers

Ralph Wetmore, Tony Stone Images

Electricity is a fundamental force of the universe. It reveals its power during a lightning storm, *above,* when huge electric charges jump between clouds or from the clouds to the ground.

Electricity

Electricity is a basic feature of the matter that makes up everything in the universe. When most people hear the word *electricity,* they think of lights, television, microwave ovens, computers, air conditioners, and other electrically powered devices. Electricity makes these and many other useful things possible. But electricity is much more important than that. Electricity and magnetism together make up a force called *electromagnetism,* one of the fundamental forces of the universe. Electrical force is responsible for holding together the atoms and molecules from which matter is composed. In this way, electricity determines the structure of every object that exists.

Electricity is also associated with many biological processes. In the human body, electrical signals travel along nerves, carrying information to and from the brain. Electrical signals tell the brain what the eyes see, what the ears hear, and what the fingers feel. Electrical signals from the brain tell muscles to move. Electrical signals even tell the heart when to beat.

Richard Wolfson, the contributor of this article, is Professor of Physics at Middlebury College.

One of the most important properties of electricity is *electric energy.* During the 1800's, people learned to harness electricity to do work. This new source of energy had so many practical applications that it greatly changed the way people lived. Inventors and scientists learned how to generate electric energy in large quantities. They found ways to use that energy to produce light, heat, and motion. They developed electric devices that enabled people to communicate across great distances and to process information quickly. The demand for electric energy grew steadily during the 1900's. Today, most people cannot imagine life without electric energy.

Uses of electric energy

Many aspects of our daily lives depend on electric energy. People living in the United States, Canada, and other developed nations use numerous electrically pow-

ered devices every day. One of the most important is the computer, which uses electric energy to process information. Computers have changed our lives at home, in school, and in the workplace.

In homes. Electric appliances, such as dishwashers, toasters, vacuum cleaners, and washing machines, save hours of labor. Electric ranges, microwave ovens, and food processors help us prepare meals quickly and easily. Refrigerators and freezers preserve food. Air conditioners and electric fans cool our homes, while electric heaters provide warmth and hot water. Television, radio, video games, compact disc players, and videocassette recorders furnish entertainment. Electric lights let us make use of the nighttime hours.

In industry. Modern industry would be impossible without electric energy. Factories produce many products on assembly lines using electrically operated conveyor belts and equipment. Manufacturers use electric instruments to ensure correct product sizes and quality. Drills, saws, and many other small tools run on electric energy. Electric motors run elevators, cranes, and most other large machinery.

In communication. Electric energy powers almost every device people use to communicate. Telephones, TV's, radios, fax machines, and computer modems all run on electric energy. Communications satellites use electric energy from devices called *solar cells* to relay information around the world. TV and radio signals are partly electrical, as are telephone, computer, and fax signals that travel along wires or thin strands of glass called *optical fibers*.

In transportation. Electric energy supplies power to subways, trolleys, and trains that carry millions of people to and from work. Most cars use electric sparks to ignite the gasoline that powers the engine. Electric devices help reduce fuel consumption and air pollution in gasoline engines. Many controls in airplanes and ships are electrically powered.

In medicine and science. Health care workers use numerous electric instruments to examine patients and perform medical tests. For example, X-ray machines and magnetic resonance imagers enable doctors to see inside our bodies. Electrocardiograph machines record tiny electrical signals from the heart, helping doctors to diagnose heart disease.

Scientists from every field use electric devices to conduct research. Microbiologists, for example, use powerful instruments called *scanning electron microscopes* to learn the secrets of living cells. Physicists use electrically operated particle accelerators to probe the interiors of atoms. Huge telescopes with electric motors help astronomers study planets, stars, and galaxies.

Electric charge

All matter in the universe, from the human body to the distant stars, is made from two kinds of tiny particles called *electrons* and *quarks*. Quarks, in turn, make up larger particles known as *protons* and *neutrons*. Electrons and quarks have a property called *electric charge*. Electrons have one kind of charge, called *negative*. Quarks have either negative charge or the opposite kind of charge, called *positive*. Protons have a positive charge the same size as an electron's negative charge because each proton contains two quarks with $\frac{2}{3}$ unit of positive charge each and one quark with $\frac{1}{3}$ unit of negative charge. Neutrons, in contrast, contain two quarks with $\frac{1}{3}$ unit of negative charge each and one quark with $\frac{2}{3}$ unit of positive charge. The charges cancel each other out, leaving the neutron electrically *neutral*, meaning it has no overall electric charge.

Opposite charges, also called *unlike charges*—negative and positive—attract one another. *Like* charges—positive and positive, or negative and negative—*repel* (push away) one another. The power to attract and repel other charges is caused by invisible influences called *electric fields* that surround each charged particle. Because of the fields, particles attract or repel one another even when they are not touching.

Atoms. Quarks combine to form protons and neutrons. Protons and neutrons, in turn, combine with elec-

David R. Frazier

David R. Frazier

Michael Newman, PhotoEdit

Electric energy can be harnessed to produce heat, motion, and light. Three useful applications of this form of energy are the electric oven, motorized shopping cart, and halogen lamp, *above*.

Terms used in electricity

Ampere is the unit used to measure the rate of flow of an electric current.
Conductor is a material through which electric current flows easily.
Electric charge is a basic feature of certain particles of matter that causes them to attract or repel other charged particles.
Electric circuit is the path that an electric current follows.
Electric current is the flow of electric charges.
Electric field is the influence a charged body has on the space around it that causes other charged bodies in that space to experience electric forces.
Electrode is a piece of metal or other conductor through which current enters or leaves an electric device.
Electromagnetism is a basic force in the universe that involves both electricity and magnetism.
Electron is a subatomic particle with a negative electric charge.
Insulator is a material that opposes the flow of electric current.
Ion is an atom or group of atoms that has either gained or lost electrons, and so has an electric charge.
Kilowatt-hour is the amount of electric energy a 1,000-watt device uses in one hour.
Neutron is a subatomic particle that has no electric charge.
Ohm is the unit used to measure a material's resistance to the flow of electric current.
Proton is a subatomic particle with a positive electric charge.
Resistance is a material's opposition to the flow of electric current.
Static electricity is electric charge that is not moving.
Voltage is a type of "pressure" that drives electric charges through a circuit.
Watt is the unit used to measure the rate of energy consumption, including electric energy.

trons to make up atoms. In an atom, protons and neutrons join to form a tiny core, called the *nucleus.*

The positively charged nucleus of an atom attracts negatively charged electrons. The nucleus has a positive charge because it contains protons but no electrons. The negative electrons whirl around the positive nucleus in somewhat the same way planets orbit the sun.

Each type of atom has a different number of protons in its nucleus. For example, hydrogen, the simplest atom, has only 1 proton in its nucleus. An oxygen atom has 8 protons. Iron has 26. Uranium has 92. Normally, an atom has an equal number of protons and electrons. As a result, the negative charges of the electrons exactly balance the positive charges of the protons. The atom is, therefore, electrically neutral.

Ions. Sometimes an atom loses or gains one or more electrons. If it gains an electron, the atom takes on a negative charge. If it loses an electron, the atom takes on a positive charge. Atoms that carry an electric charge are called *ions.* Most ions are positive, and the word *ion* used alone usually means an atom that has lost one or more electrons. Positive and negative ions attract one another and can combine to form solid materials. Ordinary table salt, for example, consists of sodium and chlorine. Each sodium atom gives up one electron to form a positive sodium ion. The chlorine takes on this electron to become a negative chloride ion. The strong electrical attraction between the ions makes salt a solid material with a high melting point.

Molecules. Neutral atoms often share electrons with other atoms. Atoms that share electrons become electrically attracted to one another. The attraction causes the atoms to join and form *molecules.* For example, two hydrogen atoms can share electrons with one oxygen atom to make a water molecule. The electrons tend to spend more time near the oxygen atom, giving it a slightly negative charge. The two hydrogen atoms take on slightly positive charges. The electric attraction between these charged atoms holds the water molecule together.

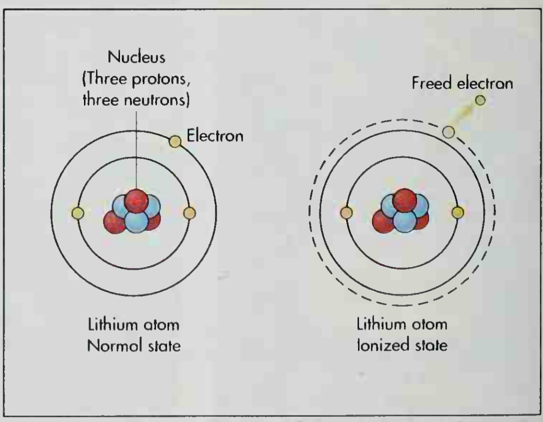
Static electricity. Sometimes, a large number of atoms in an object gain or lose electrons. When such a gain or loss happens, the entire object takes on an electric charge. The term *static electricity* describes situations where objects carry electric charge.

Static electricity occurs, for example, when you rub a balloon on your shirt. The friction between the cloth and the balloon causes electrons to transfer from your shirt to the balloon. The shirt then has an overall positive charge because it has more protons than electrons. The balloon takes on a negative charge because it has extra electrons. The balloon will then stick to the shirt or to another surface, such as a wall.

Similarly, when you walk across a rug on a dry day, friction between your shoes and the rug transfers electrons from your body to the rug, giving your body a positive charge. If you touch a doorknob or other metal object, electrons may jump from the object to your body. You may see a spark and feel a slight shock.

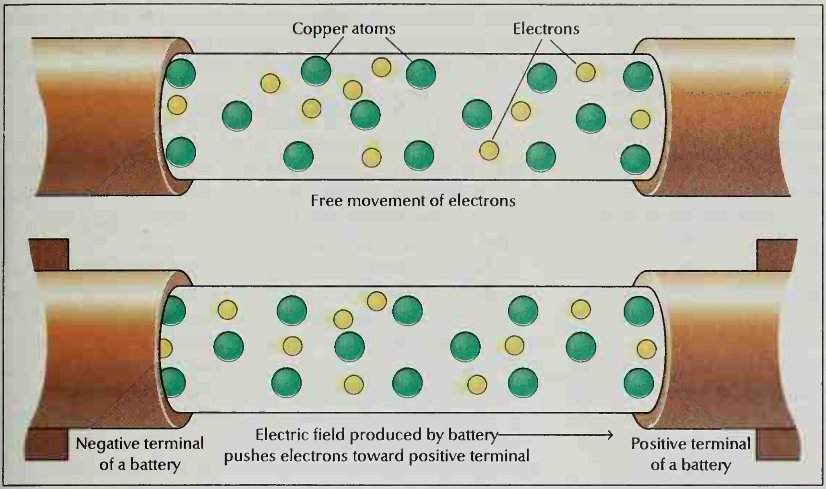
Lightning results from static electricity. Scientists believe that raindrops tossed in the winds of thunderclouds build up electric charge. Parts of the cloud become positively charged, while other parts become negatively charged. Charge may jump between different parts of the cloud, or from the cloud to the ground. The result is the huge electric spark we call lightning.

Static electricity has many uses in homes, businesses, and industries. For example, the copying machines found in most offices are *electrostatic copiers.* They make duplicates of printed or written material by attracting negatively charged particles of *toner* (powdered ink) to positively charged paper. Static electricity is also used in air cleaners called *electrostatic precipitators.* These devices put a positive electric charge on particles



WORLD BOOK diagram by Tom Brucker, Precision Graphics

An atom becomes an ion when it gains or loses an electron and so acquires an electric charge. A normal atom, *left,* has an equal number of positive protons and negative electrons. If it loses an electron, *right,* it becomes a positively charged ion.



WORLD BOOK diagram by Tom Brucker, Precision Graphics

Electric current in metals

Metals, such as copper wire, are good conductors because they have a large number of free electrons. If a copper wire is connected between the terminals of a battery, free electrons in the wire move from the negative to the positive terminal. This movement is defined as a flow of current.

of dust, smoke, bacteria, or pollen in the air. Negatively charged collector plates attract the positive particles out of the air.

Conductors and insulators

Electric charge moves through some materials better than others. Charge moves easily through substances called *conductors.* Materials known as *insulators* resist the movement of electric charge.

Conductors. Materials that conduct electricity contain charged particles that are free to move throughout the material. If extra electric charge is applied to a conductor, the charged particles will not stay in place but will spread over the material's surface. In most conductors, the free particles are electrons that are not attached to atoms. In some conductors, the free particles are ions.

Metals are good conductors because they contain a large number of free electrons. Most wires used to carry electric energy are made of metal, usually copper. Some liquids are also conductors. Salt water, for example, is a conductor because it contains sodium and chloride ions that are free to move about.

If gas is extremely hot, its atoms move so fast that they collide hard enough to tear electrons free. When this happens, the gas becomes a plasma. Plasmas are excellent conductors. The hot glowing substance inside a fluorescent light is one example of a plasma. The hot materials that make up the sun and other stars are also plasmas.

In most conductors, moving electrons continuously collide with atoms and lose energy. But in some materials, called *superconductors,* electrons move perfectly freely without losing energy. Superconductors only work at very cold temperatures. Because they require extreme cold, superconductors are only used in special situations. Someday, however, superconductors may be used to make highly efficient motors, generators, and power lines.

Insulators. In materials called insulators, electrons are tightly bound to atoms and are not free to move around. If extra electric charge is applied to an insulator, the charge will stay in place and will not move through the material. Glass, rubber, plastic, dry wood, and ordinary dry air are good insulators.

Insulators are important for electrical safety. Most electrical cords are made from a conducting material covered with an insulating material, such as rubber or plastic. The insulator makes the cords safe to touch, even when they are plugged into an outlet.

Semiconductors. Some materials conduct electric charge better than insulators but not as well as conductors. These materials are called *semiconductors.* Silicon is the most commonly used semiconductor. By adding small amounts of other substances to a semiconductor, engineers can adjust its capacity to conduct electric charge. Semiconductors are essential to the operation of computers, calculators, radios, television sets, video games, and many other devices.

Resistance refers to a material's opposition to the passage of electric charges through it. Resistance occurs when electrons moving in the material collide with atoms and give up energy. The energy the electrons give up is changed into heat. A good conductor, such as copper, has low resistance. The semiconductor silicon has higher resistance. Insulators, such as glass or wood, have such high resistance that it is nearly impossible for electric charges to flow through them. Superconductors offer no resistance to the flow of electric charges.

Resistance depends not only on the type of material but also on its size and shape. For example, a thin copper wire has more resistance than a thick one. A long wire has greater resistance than a short one. A material's resistance may also vary with temperature.

Electric current

A flow of electric charge through a conductor is called *electric current.* Energy is associated with the flow of current. As current flows through electric devices, this energy may be converted to useful forms. For example, electric energy is converted into heat by an electric range and into light by a light bulb.

Direct and alternating current. Current that flows steadily in one direction is called *direct current* (DC). A battery produces direct current. Sometimes current

flows back and forth, changing direction rapidly. It is then called *alternating current* (AC). The current in household wiring is alternating current. In the United States and Canada, household current reverses direction 120 times per second, completing 60 full cycles.

Sources of current. By itself, a conductor does not have electric current flowing in it. But if a positive charge is applied to one end of the conductor, and a negative charge to the other end, then electric charge will flow through the conductor. Because positive and negative charges attract, some type of energy must be supplied to separate the charges and keep them at opposite ends of the conductor. The energy may come from chemical action, motion, sunlight, or heat.

Batteries produce electric energy by means of chemical action. A battery has two structures called *electrodes,* each made from a different chemically active material. Between the electrodes, the battery contains a liquid or paste called an *electrolyte,* which conducts electric current. The electrolyte helps promote chemical reactions at each electrode. As a result of the chemical reactions, a positive charge builds up at one electrode and a negative charge builds up at the other. Electric current will then flow from the positive electrode, through a conductor, to the negative electrode.

In a flashlight battery, the flat end is the negative electrode. The end with a bump connects to the positive electrode. When a wire links the electrodes, a current flows. The electric energy is converted to light if it passes through a flashlight bulb. Chemical reactions in the electrolyte keep the electrodes oppositely charged and so keep the current flowing.

Eventually, the chemical energy runs out and the battery can no longer produce electric energy. Some worn-out batteries must be discarded. Others, called *rechargeable batteries,* can be charged again by passing electric current through them.

Generators change mechanical energy into electric energy. In a generator, a source of mechanical energy spins coils of wire near a magnet to produce electric current. A generator works because moving a conductor near a magnet produces a current in the conductor. Most generators produce alternating current.

Generators furnish most of the electric energy people use. In a car, a small generator called an *alternator* is turned by the engine and produces electric energy that recharges the car's battery. A large generator in an electric power plant can provide enough electric energy for a city of 2 million people. Electric current from the generator reaches homes, factories, and offices through vast networks of power lines.

Solar cells, also called *photovoltaic cells,* convert sunlight into electric energy. Solar cells power most artificial satellites and other spacecraft as well as many handheld calculators. Photovoltaic cells are made from semiconducting materials, usually specially treated silicon. Energy from the sun forces negative and positive charges in the semiconductor to separate. The charges will then flow through a conductor.

Piezoelectric crystals are nonmetallic minerals that develop electric charge along their surfaces when stretched or compressed. Quartz is the most common piezoelectric crystal. Some microphones use piezoelectric crystals to convert sound energy into electric energy for recording or radio broadcasting. Modern gas ranges have piezoelectric crystals instead of pilot lights. The crystals produce electric sparks that ignite the gas.

Electric circuits

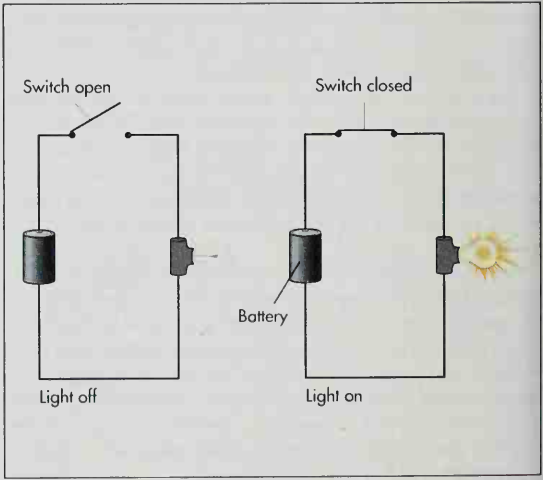
To use electric energy, an electric device must be connected to an energy source. A complete path must be provided for electric current to flow from the energy source to the device and back again. Such a path is called an *electric circuit.*

A simple circuit. Suppose you want to make a battery-powered light bulb shine. Electric current will only flow if there is a complete circuit that leads from the battery to the bulb and back to the battery. To make the circuit, connect a wire from the positive terminal of the battery to the light bulb. Then, connect another wire from the bulb back to the negative terminal. Electric current will then flow from the battery's positive terminal, through the light bulb, to the battery's negative terminal.

Inside the bulb is a thin wire called a *filament.* The filament is made from a material with greater resistance than the wires linking the battery and bulb. The moving electrons that make up the current collide with atoms in the filament and give up most of their energy. The released energy heats the filament, which glows and gives off light.

Series and parallel circuits. A single battery or generator often powers more than one electric device. In such cases, circuit designs called *series circuits* and *parallel circuits* are necessary.

A series circuit has only one path. The same current flows through all parts of the path and all electric devices connected to it. Flashlights, some Christmas tree lights, and other simple devices use series circuits. In a parallel circuit, the current splits to flow through two or more paths. Parallel circuits enable a single energy source to provide current to more electric devices than a series circuit could. Household lights and appliances are connected in parallel circuits.



WORLD BOOK diagram by Tom Brucker, Precision Graphics

An electric circuit is a path that electric current can follow between a device, such as a light bulb, and an energy source, such as a battery. With the switch open, a gap separates the connecting wires so that the current cannot complete its path.

Many circuits include some parts that are series and some that are parallel. An extremely complex circuit, like that in a computer or TV, has millions of parts connected in various series and parallel combinations.

Electric and magnetic fields. When most people think of an electric current, they think of moving electrons carrying charges through a wire. Actually, most of the energy flows in electric and magnetic fields surrounding the wire. Energy from the fields enters the wires and replaces energy the electrons lose through resistance. The battery, generator, or other energy source continually restores energy lost from the fields.

In DC circuits, electrons flow from one battery terminal, through the circuit, to the other terminal. But the energy of the electric and magnetic fields flows at the same time from both terminals to the electric device. In AC circuits, individual electrons move back and forth in the wires and do not travel the entire circuit. Nevertheless, electric energy flows from the energy source to the device in the form of the fields.

Controlling electric current. The simplest way to stop a current flowing through a circuit is with a *switch.* A basic switch consists of two electric conductors that can be moved apart to create a gap in a circuit. When the switch is off, the gap is open, and no current flows. When the switch is on, the conductors are connected, and current flows.

Wires and electric devices become dangerously hot if too much current flows through them. Switches called *fuses* and *circuit breakers* protect the wiring in most buildings. If too many electric devices are plugged into an outlet, a fuse or circuit breaker will shut off the current. Many individual electric devices also contain fuses.

Sometimes people need to vary the strength of current, rather than merely turn it on or off. One way to adjust current strength is to vary resistance within the circuit. For example, turning the volume knob on a radio operates a *variable resistor.* This device adjusts resistance to the flow of current through the radio, making the sound louder or softer.

Switches and variable resistors cannot change currents quickly. Tiny semiconductor devices called *transistors* can be used to adjust current more rapidly. Transistors act as high-speed switches that turn on and off billions of times each second. Some devices contain millions of transistors on a single tiny chip of silicon, called an *integrated circuit* or simply a *chip.* Integrated circuits form the heart of computers, calculators, video games, and many other devices.

Electrically powered devices are said to be *electronic* if they carry electrical signals that can be varied in some way to represent information. Electronic devices include transistors, diodes, capacitors, inductors, and integrated circuits. Signals may represent sounds, pictures, numbers, letters, computer instructions, or other information. In the amplifier of a compact disc player, for example, transistors provide a continuous range of currents that strengthen electrical signals representing the sounds being played.

Electrical safety

Most people know that electricity can be dangerous. Understanding why can help you avoid electrical injury and use electric energy safely.

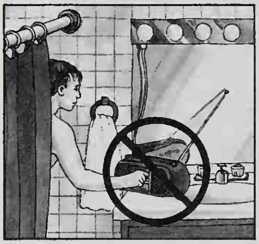
Electric shock is caused by an electric current passing through the body. The body's own electrical signals normally travel along nerves, carrying information to and from the brain. These electrical signals regulate the beating of the heart and other vital functions. Currents flowing through the body can disrupt these signals, causing muscle contractions, heart and respiratory failure, and death. Electric current can also burn skin and other body tissues.

Voltage measures the "push" that a source of electric energy supplies to move a charge through a circuit. The voltage of a flashlight or radio battery is usually too

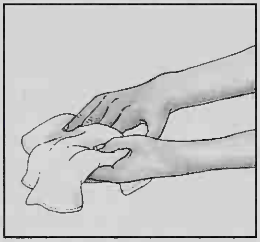
Safety with electricity

Electricity can be dangerous. But following certain precautions can help you avoid electrical injury.

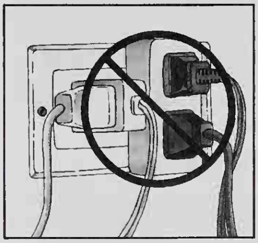
WORLD BOOK illustrations by Yoshi Miyake



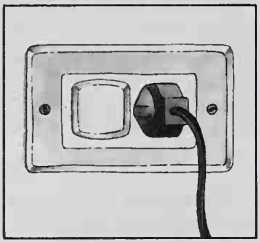
Do not touch electric devices when you are in a shower or bathtub or when you are wet.



Dry your hands thoroughly before using a hairdryer, electric shaver, or other electric appliance.



Do not overload electrical outlets. Never plug in an electric device that has a damaged cord.



Insert safety plugs into unused electrical outlets within reach of children.

Do not fly kites or climb trees near power lines. Never go near fallen power lines after a storm.

Find shelter indoors during a lightning storm. Use the telephone only in emergencies.

small to cause serious injury. But the 120 volts available at most household outlets could severely injure or even kill a person. The danger of electric shock is much greater when a person's skin is wet because water, mixed with salt from the skin, lowers the body's electrical resistance. A given voltage can then pass a greater current through the body. For information about first aid for electric shock, see **First aid**.

Most electric devices have safety features to help prevent shock. Many appliances and tools have plugs with a third prong that connects the metal parts of the device to a wire leading to the ground. If the wiring inside the device becomes defective, the third prong usually causes the current to flow harmlessly to the ground.

Electrical dangers outdoors. If you climb a tree near an electric power line, you may get a shock if the tree touches the line. Storms sometimes knock down electric power lines. You could be injured or killed if you touch a fallen line when the power is still on.

Lightning discharges involve about 100 million volts. This voltage is more than enough to drive a current through the body that can kill a person. You can avoid being struck by lightning by staying indoors during a storm. If you get caught outdoors, stay away from open fields and high places. A forest is safer than open land. But do not stand under a tall or isolated tree, which is more likely to be struck. One of the safest places during a lightning storm is inside a car. If the vehicle is struck by lightning, its metal body will conduct the electric charge around the outside of the car, leaving the interior unharmed.

Electrical fire is another danger. When an electric current passes through a conductor, resistance causes the conductor to become hot. Sometimes the heat is desirable. For example, the wires in a toaster heat up to brown bread. But overheating in electrical cords or in household wiring can cause a fire. Electrical fires destroy many homes every year. To avoid fires, do not plug too many devices into the same outlet, and never use electric devices with worn or frayed cords.

Electricity and magnetism

The magnet you stick to your refrigerator may not seem related to electricity. But magnetism and electricity are actually closely related. Just as an electric field surrounds an electric charge and produces a force that affects other charges, so a *magnetic field* surrounds a magnet and produces forces that act on other magnets. Like an electric charge, a magnet will attract or repel another magnet. Moreover, magnetism is the result of electric currents. In materials called *permanent magnets,* the currents come from the motions of electrons in some of the atoms. The electrons spin on their axes like tops, and they also circle the atomic nuclei.

Together, magnetism and electricity make a fundamental force of the universe called electromagnetism. Electromagnetism is based on the fact that the motion of electric charges can produce magnetic fields, and changing magnetic fields can produce electric currents.

For example, passing an electric current through a coil of wire makes the coil a temporary magnet called an *electromagnet.* The electric current creates a magnetic field around the coiled wire. As long as the current flows, the coil will be a magnet.

Magnetism can, in turn, produce an eiectric current by means of *electromagnetic induction.* In this process, a coil of wire moves near a magnet. This action causes an electric current to flow in the wire. The current flows as long as the movement continues. Generators produce electric current through this process.

Together, changing electric and magnetic fields make *electromagnetic waves,* also called *electromagnetic radiation.* These waves carry energy known as *electromagnetic energy* at the speed of light. Light, radio and TV signals, and microwaves all consist of electromagnetic waves. So do the infrared rays that you feel as heat when you stand near a hot stove, and the ultraviolet rays that cause sunburn. The X rays that doctors use to see inside your body are electromagnetic waves. The gamma rays that come from nuclear reactors and from outer space are also electromagnetic waves.

History

Early discoveries. Several thousand years ago, the ancient Greeks observed that a substance called *amber* attracted bits of lightweight material, such as feathers or straw, after it was rubbed with cloth. Amber is fossilized pitch from pine trees that lived millions of years ago. Amber is a good electric insulator, so it easily holds electric charge. Although the Greeks did not know about electric charge, they were actually experimenting with static electricity when they rubbed amber. The Greek word for amber is *elektron.* The English words *electricity* and *electron* come from this word.

Other peoples, including the ancient Greeks and Chinese, knew of another substance that could attract things. It was a black rock called *lodestone* or *magnetite.* Today we know that it is a natural magnet. Lodestone attracts iron objects, which tend to be heavy. In contrast, amber attracts only light things, like straw. In 1551, the Italian mathematician Girolamo Cardano, also known as Jerome Cardan, realized that the attracting effects of amber and of magnetite must be different. Cardano was the first to note the difference between electricity and magnetism.

In 1600, the English physician William Gilbert reported that such materials as glass, sulfur, and wax behaved like amber. When rubbed with cloth, they too attracted light objects. Gilbert called these materials *electrics.* He studied the behavior of electrics and concluded that their effects must be due to some kind of fluid. Today, we know that what Gilbert called electrics are materials that are good insulators.

Experiments with electric charge. In the 1730's, the French scientist Charles Dufay found that charged pieces of glass attracted amberlike substances but repelled other glasslike substances. Dufay decided that there must be two kinds of electricities. He called them *vitreous* (for glasslike substances) and *resinous* (for amberlike substances). Dufay had found negative and positive electric charge, though he thought of them as two kinds of "electric fluid."

The American scientist and statesman Benjamin Franklin began to experiment with electricity in 1746. Franklin thought that there was only one kind of electric fluid. He theorized that objects with too much fluid would repel each other, but they would attract objects with too little fluid. If an object with an excess of fluid

touched an object deficient in fluid, the fluid would be shared. Franklin's idea explained how opposite charges cancel each other out when they come in contact.

Franklin used the term *positive* for what he thought was an excess of electric fluid. He used the term *negative* for a deficiency of fluid. Franklin did not know that electricity is not a fluid. Rather, electricity is associated with the charges of electrons and protons. Today, we know that most positively charged objects actually have a deficiency of electrons, while negatively charged objects have an excess of electrons.

In 1752, Franklin performed his famous experiment of flying a kite during a thunderstorm. When the kite and string became electrically charged, Franklin concluded that the storm clouds were themselves charged. He became convinced that lightning was a huge electric spark Fortunately, lightning did not strike Franklin's kite. If it had, he probably would have been killed.

In 1767, the English scientist Joseph Priestley described the mathematical law that shows how attraction weakens as the distance between oppositely charged objects increases. In 1785, the French scientist Charles Augustin de Coulomb confirmed Priestley's law. Coulomb showed that the law also held true for the repulsive force between objects with the same charge. Today, the principle is known as *Coulomb's law.*

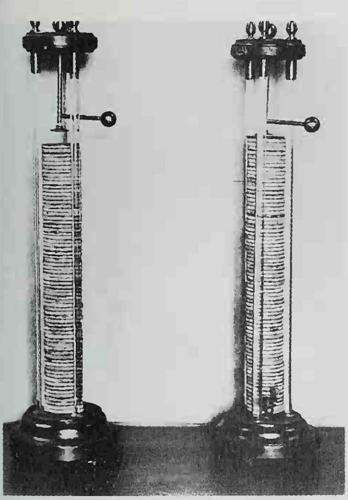
In 1771, Luigi Galvani, an Italian anatomy professor, found that the leg of a recently killed frog would twitch when touched with two different metals at the same time. Galvani's work attracted much attention. In the late 1790's, Alessandro Volta, an Italian physicist, offered an explanation. Volta showed that chemical action occurs in a moist material in contact with two different metals. The chemical action results in an electric current. The flow of current had made Galvani's frog twitch. Volta gathered pairs of disks, consisting of one silver and one zinc disk. He separated the pairs with paper or cloth moistened with salt water. By piling up a stack of such disks, Volta constructed the first battery, called a *voltaic pile.*

Many experiments with Volta's battery and electric circuits followed. The German physicist Georg S. Ohm devised a mathematical law to describe the relationship between current, voltage, and resistance for certain materials. According to Ohm's law, published in 1827, a larger voltage can push a larger current through a given resistance. In addition, a given voltage can push a larger current through a smaller resistance.

Electricity and magnetism. In 1820, the Danish physicist Hans C. Oersted found that an electric current flowing near a compass needle will cause the needle to move. Oersted was the first to show a definite connection between electricity and magnetism. During the 1820's, André Marie Ampère discovered the mathematical relationship between currents and magnetic fields. That relationship, called Ampère's law, is one of the basic laws of electromagnetism.

In the early 1830's, the English scientist Michael Faraday and the American physicist Joseph Henry independently discovered that moving a magnet near a coil of wire produced an electric current in the wire. Further experiments showed that electrical effects occur any time a magnetic field changes. Audio and videotape recording, computer disks, and electric generators are based on this principle.

The Scottish physicist James Clerk Maxwell combined all the known laws covering electricity and magnetism into a single set of four equations. Maxwell's equations, published in 1865, describe completely how electric and magnetic fields arise and interact. Maxwell made a new prediction that a changing electric field would produce a magnetic field. That prediction led him to propose the existence of electromagnetic waves, which we now know include light, radio waves, and X rays. In the later 1880's, the German physicist Heinrich R. Hertz showed how to generate and detect radio waves, proving Maxwell correct. In 1901, the Italian inventor Guglielmo Marconi transmitted electromagnetic waves across the Atlantic Ocean, setting the stage for radio, TV, satellite communications, and cellular telephones.



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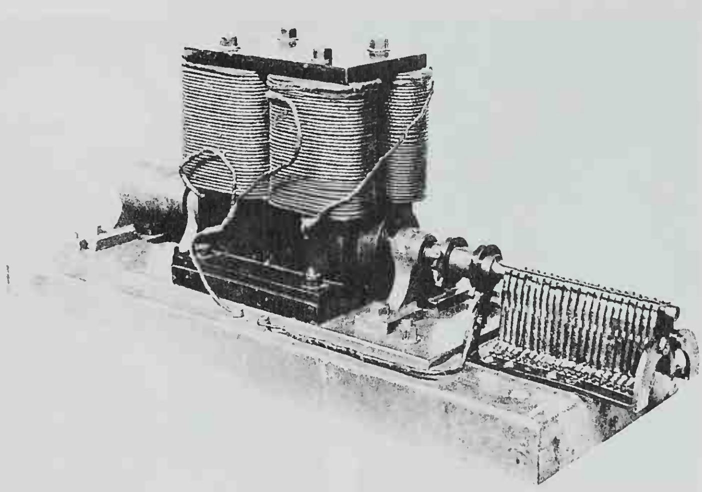
The voltaic pile, invented in the late 1790's, was the first battery. It provided the first source of steady electric current.



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The dynamo was the first efficient electric generator. It used an electromagnet to produce current, instead of the permanent magnets previously employed. The German inventor Ernst Werner von Siemens discovered the principle of the dynamo in 1866.

The electronic age. The Irish physicist G. Johnstone Stoney believed that electric current was actually the movement of extremely small, electrically charged particles. In 1891, he suggested that these particles be called *electrons.* In 1897, the English physicist Joseph John Thomson proved the existence of electrons and showed that all atoms contain them. In research published in 1913, the American physicist Robert A. Millikan accurately measured the electron's charge.

In the late 1800's, scientists discovered that electrons can be dislodged from a metal surface in a *vacuum tube.* A vacuum tube is a glass tube with most of the air removed. The tube contains electrodes with wires that extend through the glass. Linking batteries to the electrodes causes a current of electrons to flow within the tube. The current can be modified by adjusting the voltage. Vacuum tubes can amplify, combine, and separate weak electric currents. This invention helped make radio, TV, and other technologies possible.

In 1947, the American physicists John Bardeen, Walter H. Brattain, and William Shockley invented the transistor. Transistors do the same jobs as vacuum tubes, but they are smaller and more durable, and they use far less energy. By the 1960's, transistors had replaced vacuum tubes in most electronic equipment. Since then, electronics companies have developed ever smaller transistors. Today, millions of interconnected transistors fit on a single chip called an integrated circuit.

Recent developments. Every year, the worldwide demand for electric energy increases. Most of the electric energy we use comes from power plants that burn fossil fuels, such as coal, oil, or natural gas. Some electric energy comes from nuclear and *hydroelectric* (water power) plants. Smaller amounts come from solar cells, windmills, and other sources.

Many people are concerned that the earth's supply of fossil fuel is limited and will someday run out. Another problem is that present methods of generating electric energy may harm the environment. In response, scientists, engineers, and power companies are trying to develop alternative sources of electric energy. Such sources may include solar, geothermal, wind, and tidal energy. See **Energy supply** (Problems; Challenges).

Many scientists hope that new electric devices will actually help curb the growing demand for electric energy. Computers, for example, can control the lights, air conditioning, and heating in buildings to reduce energy use. Compact fluorescent lamps, using miniature electronic circuits, provide the same light as ordinary light bulbs but use only one-fourth as much electric energy. Computers and modern communication systems enable people to work at home and save energy they would have used for transportation. Richard Wolfson

Related articles in *World Book.* See Electronics and Magnetism and their lists of *Related articles.* See also:

Biographies

Ampère, André Marie	Hertz, Heinrich Rudolph
Bell, Alexander Graham	Latimer, Lewis Howard
Coulomb, Charles Augustin de	Marconi, Guglielmo
De Forest, Lee	Maxwell, James Clerk
Edison, Thomas Alva	Millikan, Robert Andrews
Faraday, Michael	Morse, Samuel Finley Breese
Franklin, Benjamin	Oersted, Hans Christian
Galvani, Luigi	Ohm, Georg Simon
Gilbert, William	Siemens, Ernst Werner von
Gray, Elisha	Thomson, Sir Joseph John
Henry, Joseph	Volta, Alessandro

Basic principles of electricity

Atom	Electromagnetism	Lenz's law
Electric arc	Electromotive force	Matter
Electric circuit	Electron	Molecule
Electric current	Hall effect	Ohm's law
Electric field	Inductance	Plasma (physics)
Electric power	Induction, Electric	Proton
Electrochemistry	Ion	

Creating and controlling electric energy

Armature	Electric generator	Fuel cell
Battery	Electric switch	Fuse (electricity)
Capacitor	Electrode	Induction coil
Circuit breaker	Electrolysis	Insulator, Electric
Electric eye	Electrolyte	Leyden jar

David R. Frazier

The vacuum tube led to the development of radio and television. This large early tube was made about 1922.

Fermi National Accelerator Laboratory

A particle accelerator helps scientists study electricity and other natural forces. The accelerator at the Fermi National Accelerator Laboratory near Batavia, Illinois, accelerates protons to almost the speed of light in an underground tunnel, *shown here.*

Magnetic amplifier
Magneto
Nuclear energy
Piezoelectricity
Solar energy
Thermocouple
Transformer
Turbine
Van de Graaff generator
Water power
Wind power

Measuring electric energy

Ampere
Coulomb
Electric meter
Electroscope
Farad
Henry
Joule
Kilowatt
Ohm
Oscilloscope
Potentiometer
Volt
Watt
Wattmeter
Wheatstone bridge

Uses of electric energy

Air conditioning (How air conditioning works)
Automobile (The electrical system)
Cable
Ceramics (Electrical equipment)
Clock (Electric clocks)
Electric car
Electric light
Electric motor
Electric railroad
Electrophoresis
Electroplating
Flashlight
Heating (Electric power)
Ignition
Linear electric motor
Locomotive (Electric locomotives)
Machine tool (Advanced machine tool operations)
Microphone
Particle accelerator (How accelerators work)
Rocket (Electric rockets)
Signaling (Electrical signals)

Other related articles

Amber
Electric eel
Electric fish
Electric ray
Electrocution
Electromotive series
Energy
Energy supply
Engineering (Electrical engineering)
Fire prevention (In homes and schools)
First aid (Restoring breathing)
Human body (The peripheral nervous system)
Light (The nature of light)
Lightning
Lightning rod
Lodestone
Materials (Electrical properties)
Nervous system (How neurons carry impulses)
Safety (Safety with electricity)

Outline

I. Uses of electric energy
- A. In homes
- B. In industry
- C. In communication
- D. In transportation
- E. In medicine and science

II. Electric charge
- A. Atoms
- B. Ions
- C. Molecules
- D. Static electricity

III. Conductors and insulators
- A. Conductors
- B. Insulators
- C. Semiconductors
- D. Resistance

IV. Electric current
- A. Direct and alternating current
- B. Sources of current

V. Electric circuits
- A. A simple circuit
- B. Series and parallel circuits
- C. Electric and magnetic fields
- D. Controlling electric current

VI. Electrical safety
- A. Electric shock
- B. Electrical dangers outdoors
- C. Electrical fire

VII. Electricity and magnetism

VIII. History

Questions

What purpose do fuses and circuit breakers serve?
If an atom has more protons than electrons, what kind of charge will the atom have?
How are insulators important to electrical safety?
What device produces electric energy by chemical action?
Why does metal conduct electric current better than wood?
How are electricity and magnetism related?
What familiar office machine uses static electricity?
Why can you make a balloon stick to your shirt?
What should you do if you are caught outdoors during a lightning storm?
How has electric energy changed the way people live?

Additional resources

Level I
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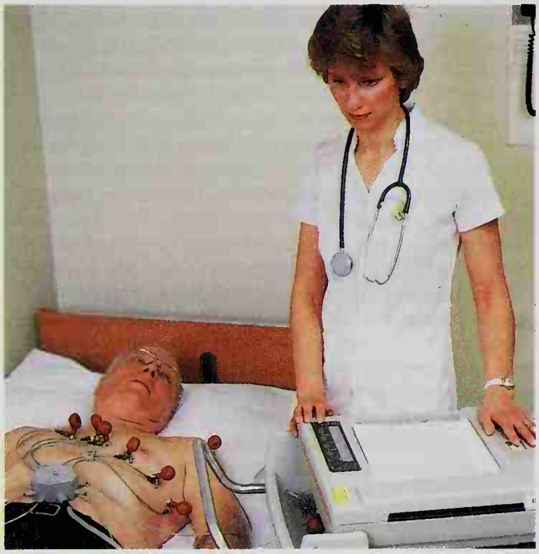
Gibson, Gary. *Understanding Electricity.* Copper Beech, 1995.
Levine, Shar, and Johnstone, Leslie. *Shocking Science: Fun & Fascinating Electrical Experiments.* Sterling Pub., 1999.
Oxlade, Chris. *Electricity & Magnetism.* Heinemann Lib., 2000.

Level II
Cauldwell, Rex. *Safe Home Wiring Projects.* Taunton Pr., 1997.
Gibilisco, Stan. *Teach Yourself Electricity & Electronics.* 2nd ed. McGraw, 1997.
Nye, David E. *Electrifying America.* MIT Pr., 1990.
Perlin, John. *From Space to Earth: The Story of Solar Electricity.* aatec, 1999.

Electrocardiograph is an instrument used to diagnose heart disorders. Each time the heart beats, it produces electrical currents. These currents are responsible for the rate and pattern of contraction of the heart. An electrocardiograph picks up and records these cur-



WORLD BOOK photo by Ralph Brunke

An electrocardiograph picks up and records electrical currents produced by the heart. The currents are picked up by *electrodes*—metal strips that conduct electric current—that are attached to the patient's body. The electrocardiograph amplifies the currents and records them on paper as a series of wavy lines.

rents. The electrocardiograph may be connected to a printer, which prints a record called an *electrocardiogram,* often abbreviated *ECG* or *EKG.* The electrocardiograph may also be connected to an *oscilloscope,* an instrument that displays the currents on a TV-type screen.

An electrocardiograph contains amplifying and recording equipment. Wires run from the machine to *electrodes*—strips of metal that conduct electricity. The electrodes are attached to the patient's skin with a special jelly. Electrodes are placed on each arm and leg and at six points on the chest over the area of the heart.

The electrodes pick up the currents produced by the heartbeat and transmit them to an amplifier inside the electrocardiograph. The amplified currents then flow through a very fine wire coil that hangs suspended in a magnetic field. As these currents react with the magnetic field, they move the wire. In most electrocardiographs, a sensitive lever traces the wire's motions on a moving paper chart, producing the electrocardiogram.

Each heartbeat produces a series of wavy lines on the ECG. A normal heartbeat makes a specific pattern of waves. Certain kinds of heart damage and disease change the pattern in recognizable ways.

Physicians use ECG's to diagnose heart damage from such conditions as high blood pressure, rheumatic fever, and birth defects. An ECG also helps determine the location and the amount of injury caused by a heart attack, and follow-up ECG's show how the heart is recovering. An ECG can also reveal irregularities in the heart's rhythm, known as *arrhythmias.* In addition, physicians sometimes use an ECG to determine the effects of certain drugs on the heart.

An ECG is usually taken while the patient is lying down. This procedure is called a *resting ECG.* Sometimes, an ECG is taken while the patient is exercising or after the patient has received medication to stimulate the heart. This test, called a *stress ECG,* indicates whether the heart receives enough oxygen during vigorous activity. Doctors use a stress ECG to diagnose *coronary artery disease.* See **Heart** (Coronary artery disease; Heart attack; picture: Rehabilitation); **Stress test.**

The electrocardiograph developed from the string galvanometer, invented in 1903 by the Dutch physiologist Willem Einthoven (see **Einthoven, Willem**). The electrocardiograph was first used in the United States in 1909. Julius M. Gardin

Electrochemistry is a science that deals with chemical reactions that involve electricity. Most electrochemical reactions take place in a vessel that has two electrodes surrounded by an *electrolyte.* An electrolyte is a substance that conducts electricity. Electrochemical processes are used to produce chemicals and electricity, to refinish and plate metals, and to conduct research.

Some electrochemical processes produce electricity from chemical changes, and others use electricity to produce chemical changes. A series of reactions among the chemicals in a battery, for example, produce an electric current (see **Battery**). A similar process occurs in *fuel cells.* Such cells use hydrogen and oxygen, or methanol and oxygen, to produce electricity (see **Fuel cell**). In a process called *electrolysis,* an electric current passing through a chemical solution separates certain elements from the solution. For example, manufacturers make chlorine by passing electricity through salt water. Electrolysis is also used to separate aluminum, magnesium, and certain other metals from molten salts. Some metals are plated by means of electrolysis (see **Electrolysis; Electroplating**).

The corrosion of metals in the presence of moisture is a naturally occurring electrolytic process. Electrochemists study corrosion to develop ways to protect metals. Electrochemical studies also include the *electroanalysis* of solutions and other chemical systems. In electroanalysis, the composition of such systems is studied by observing their response to electrical signals.

Electrochemistry includes several special fields. Scientists in the field of *photoelectrochemistry* seek ways of using light energy to produce electricity or chemical changes. *Bioelectrochemistry* deals with electrochemical processes that occur in the body. Such electrochemical processes include the production of brain waves and nerve impulses. Allen J. Bard

Electrocution is a means of killing a person by the use of a strong electric shock. Accidental electrocution occurs when a person accidentally comes in contact with, and is killed by, a powerful charge of electricity.

Electrocution has also been used as a legal method of executing criminals. A prisoner is brought into a special room called a *death chamber,* and strapped into an *electric chair.* Metal plates called *electrodes* are attached to the crown of the prisoner's head and to the calf of one leg. An electric current is then passed from one electrode to another through the prisoner's body. The current is strong enough to produce immediate loss of consciousness and almost immediate death. Medical experts believe a person feels no pain when being electrocuted.

In 1890, New York became the first state in the United States to execute a criminal using electrocution. For a list of the states that use electrocution as a method of executing criminals, see **Capital punishment** (table).

George T. Felkenes

Electrode is a conductor through which current enters or leaves an electric or electronic device. Most electrodes are pieces of metal shaped into plates, rods, wires, or wire mesh.

A battery has two electrodes—one positively charged and one negatively charged. When they are connected to an external circuit, the battery produces current.

Vacuum tubes and solid-state electronic devices have two or more electrodes. Voltages are applied to the electrodes from the outside, and the electrodes establish and maintain the desired voltages and electric fields within the device. The flow of current within the device can be controlled by varying the voltages applied to the electrodes. Robert B. Prigo

See also **Battery; Electrolysis; Neon; Vacuum tube.**

Electroencephalograph, *ih LEHK troh ehn SEHF uh luh graf,* is an instrument used to measure and record the electrical voltages produced by *neurons* (nerve cells) in the brain. A recording of this electrical activity is called an *electroencephalogram.* Both electroencephalograph and electroencephalogram are abbreviated EEG. Doctors and neuroscientists use the electroencephalograph to study normal brain activity. They also use it to study abnormal brain states that are caused by injury, tumors, infection, or even death.

To record an electroencephalogram, medical person-

nel attach electrodes from the electroencephalograph to the patient's scalp. The electroencephalogram is usually recorded on a long, moving chart paper using ink pens that *oscillate* (move back and forth) with changes in the brain's electrical activity. When the patient is relaxed with the eyes closed, the oscillations normally form a pattern that repeats approximately 10 times a second. Such brain waves are called *alpha waves.* When the person is alert and concentrating, the alpha waves tend to disappear and are replaced by smaller and faster *beta waves.* When a person is in a deep sleep, very large and slow *theta waves* and *delta waves* occur.

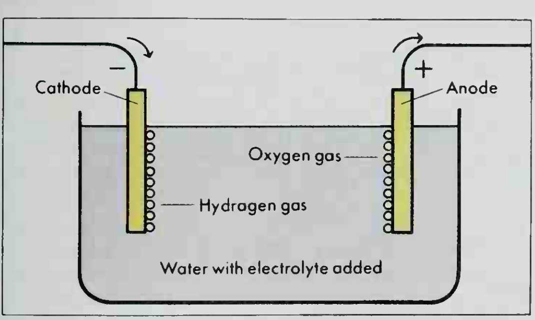
One of the most common medical applications of the electroencephalograph is to diagnose and study epilepsy. In epilepsy, abnormal discharges of certain neurons cause excessive electrical activity that interferes with normal brain function, resulting in a seizure. The electroencephalograph is used to detect and locate the brain regions that are responsible for seizures.

Daniel S. Barth

Electrolysis, *ih LEHK TRAHL uh sihs,* is a process in which an electric current is passed through a liquid, causing a chemical reaction to take place. If the liquid is water, electrolysis "breaks up" the water into two gases—hydrogen and oxygen. If the liquid is a solution that contains a metal, electrolysis breaks up the solution so that the metal is removed. The electrolysis of metallic solutions is useful in putting metal coatings on objects, and in refining, or purifying, metals.

How electrolysis works. To produce electrolysis, two solid electrical conductors, such as metal or graphite rods, are placed into a liquid. The rods are called *electrodes.* Wires connect the electrodes to the terminals of a battery or to a direct current generator. The liquid must contain a substance, called an *electrolyte,* that enables it to carry the current and complete the electrical circuit. For example, distilled water cannot be electrolyzed because it does not conduct electricity well. But it can be electrolyzed if a little table salt (sodium chloride), which is an electrolyte, is added to it. The electrodes, the liquid, and the container that holds them make up an *electrolytic cell.*

The electrode connected to the battery's negative pole is the *cathode.* It carries electrons from the battery to the electrolytic cell. The electrode connected to the battery's positive pole is the *anode.* It carries electrons from the electrolytic cell back to the battery.



WORLD BOOK diagram by Sarah Woodward

How electrolysis works. In the electrolysis of water, the hydrogen gas collects at the cathode and the oxygen gas collects at the anode. The arrows show the direction of electron flow.

As the current flows through the electrolytic cell, chemical changes take place at the surfaces of the electrodes. At the cathode, the electrolyzed liquid combines with electrons supplied by the battery. This process is called *reduction.* At the anode, the liquid gives electrons to the anode. This process is called *oxidation.*

In the electrolysis of water, the water combines with electrons at the cathode and is *reduced* to hydrogen gas. At the anode, water gives up electrons and is *oxidized* to oxygen gas. The volume of the hydrogen produced is always twice the volume of the oxygen produced, because water contains two atoms of hydrogen for each atom of oxygen. The chemical equation for the processes that occur in the electrolysis of water is

$$2H_2O \rightarrow 2H_2\uparrow + O_2\uparrow$$

In the electrolysis of solutions containing *ions* (charged atoms) of such metals as copper and silver, the reduction of the metal at the cathode causes the metal to be deposited, or to *plate out,* on the cathode.

Uses of electrolysis. Electrolysis plays an important part in industry. Sodium metal is produced by the electrolysis of molten sodium chloride. In this process, chlorine gas is produced at the anode. Both sodium metal and chlorine gas have many important industrial and chemical uses. The electrolysis of sodium chloride dissolved in water forms another important chemical, sodium hydroxide (caustic soda).

Magnesium, aluminum, and certain other metals are produced commercially by electrolysis. Aluminum metal is made by electrolysis of alumina dissolved in the molten mineral, cryolite. Copper and other minerals are purified by electrolysis. A bar of impure copper is made the anode and a bar of pure copper is made the cathode. During electrolysis, the impure copper anode is dissolved into copper ions (Cu^{2+}). The pure copper it contains plates out on the cathode. All impurities fall to the bottom of the electrolytic cell and are removed later.

Important chemicals produced commercially by electrolysis include manganese dioxide, hydrogen peroxide, chlorates, and perchlorates. Hydrogen peroxide and perchlorates are used in rocket fuels. Electrolysis is also used to *anodize* metals to make their surfaces more decorative and resistant to corrosion.

Laws of electrolysis. The English chemist Michael Faraday was one of the first scientists to investigate electrolysis. After many careful experiments and calculations, he stated the following three "laws":

1. The ability of an electric current to cause electrolysis does not depend on the distance between electrodes.
2. The quantity of a substance that is electrolyzed is proportional to the quantity of the electricity used.
3. The quantity of a substance that is electrolyzed is also proportional to the substance's chemical equivalent. The *chemical equivalent* of a metal is its *atomic weight* (in grams) divided by its *valence.*

Faraday found that approximately 96,500 coulombs of electricity are required to electrolyze one chemical equivalent of any metal. For example, the atomic weight of copper is 63.54, and the valence of copper salts is +2. Therefore, the chemical equivalent of a copper salt solution is 31.77 grams. This much copper will plate out when about 96,500 coulombs pass through the solution.

The number of coulombs that flow in each second is measured in units called *amperes. Voltage* is like an electrical pressure that pushes the coulombs through the circuit. In electrolysis, voltage is just as important as amperage. A certain minimum voltage is needed to produce electrolysis in any given substance. For example, a minimum of 1.23 volts is needed to electrolyze water to hydrogen and oxygen at 25 °C. Mark S. Wrighton

Related articles in *World Book* include:

Anodizing
Electric current
Electricity
Electrochemistry
Electrode
Electrolyte
Electroplating
Faraday, Michael
Ion
Magnesium (How magnesium is obtained)
Metallurgy

Electrolyte, *ih LEHK truh lyt,* is a substance that conducts electricity. Most electrolytes must be dissolved in water or some other solvent. A battery contains an electrolyte in either a liquid or a pasty solution. Liquid electrolytes are used in electrolysis, electroplating, and other chemical processes.

When an electrolyte dissolves, it releases positive and negative *ions* (electrically charged atoms or groups of atoms). These released ions carry electric charges between electrodes immersed in the solution. *Cations* carry positive electric charges toward the *cathode* (negative electrode). *Anions* carry negative electric charges toward the *anode* (positive electrode).

Strong electrolytes release many ions and conduct electricity well. These electrolytes include strong acids and bases, and most salts. *Weak* electrolytes, such as acetic acid, release few ions and conduct poorly. *Nonelectrolytes,* such as sugar, release no ions and form nonconducting solutions.

A few electrolytes conduct electricity as solids. In these *solid electrolytes,* the ions can move and carry charges without adding a solvent. Allen J. Bard

See also **Battery; Electrolysis; Electroplating; Ion.**

Electromagnet is a temporary magnet formed when electric current flows through a wire or other conductor. Most electromagnets consist of wire wound around an iron core. This core is made from magnetically soft iron that loses its magnetism quickly when the electric current stops flowing through the wire.

Electromagnets drive electric doorbells, buzzers, and relays. They also produce the magnetic fields needed to make electric motors and generators work. Powerful industrial electromagnets lift heavy pieces of scrap iron. Specially designed electromagnets create the very strong magnetic fields that guide atomic particles along desired paths in particle accelerators.

In 1820, Danish physicist Hans Oersted discovered that an electric current produces a magnetic field. In 1825, English electrician William Sturgeon showed that an iron core strengthens a coil's magnetic field. American physicist Joseph Henry built the first practical electromagnet in the late 1820's. George Vahala

See also **Electromagnetism; Henry, Joseph; Linear electric motor; Superconductivity; Plasma.**

Electromagnetic theory of light. See **Light** (The electromagnetic theory); **Electromagnetic waves.**

Electromagnetic waves are related patterns of electric and magnetic force. They are generated by the *oscillation* (movement back and forth) of electric charges. Electromagnetic waves travel through space at the speed of light—186,282 miles (299,792 kilometers) per second. The simplest electromagnetic waves are *plane waves.* They move through space in straight lines. The strength of the wave varies in space and time with alternating crests and troughs. The distance from crest to crest is called the *wavelength.* See **Light** (diagram: Electromagnetic nature of light).

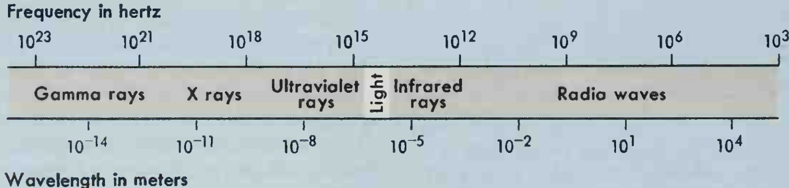
The electromagnetic spectrum consists of bands of different wavelengths. The chief kinds of electromagnetic waves are—in order of increasing wavelength—gamma rays, X rays, ultraviolet light, visible light, infrared rays, microwaves, and radio waves. Gamma rays are less than 10-trillionths of a meter in length, and some long radio waves measure more than 10,000 kilometers.

All types of electromagnetic waves have the properties of visible light. They can be reflected, *diffracted* (spread), and *refracted* (bent). The direction of magnetic force in all electromagnetic waves is perpendicular to the direction in which the wave is moving. The direction of electric force is perpendicular to both the direction of magnetic force and the direction of wave motion. The strength of magnetic force always equals the strength of electric force.

Uses of electromagnetic waves. Doctors use gamma rays, which are given off by radium, to treat cancer. They also use X rays to treat cancer and to help locate and diagnose internal disorders. Ultraviolet rays are

The electromagnetic spectrum

The electromagnetic spectrum extends from short gamma rays through light waves to long radio waves. The spectrum diagrammed below gives the frequency and wavelength for the various waves. Frequencies are given in hertz and wavelengths in meters. The raised figures with the 10's are a way of abbreviating numbers. For example, 10^{15} hertz equals 1 followed by 15 zeroes, or 1,000,000,000,000,000 hertz. The numbers with a minus sign tell how many places the decimal point must be moved in front of the number. For example, 10^{-7} meters equals 0.0000001 meter.



used in sun lamps and fluorescent lights and as a disinfectant. Infrared rays, which are given off by hot objects, are used in infrared lamps to treat skin diseases and to bake enamel. Microwaves are used to cook food. Radio waves are used in radio and TV broadcasting.

The use of electromagnetic waves depends on the ease with which the various wavelengths can be detected and produced. Wavelength is related to the vibration rate of electrons in the energy source. The slower the vibration, the longer the wavelength. Long waves are the easiest to produce, and the use of radio waves in communications began soon after 1900. Shorter waves were not used effectively until the development of such devices as the klystron, a type of microwave tube (see **Vacuum tube**). Development of the laser during the 1960's provided new uses for short waves. For example, the laser enables ultraviolet and infrared rays to transmit voice messages and television signals (see **Laser**).

History. In 1864, the British physicist James Clerk Maxwell predicted the existence of electromagnetic waves. Maxwell assumed that electric and magnetic fields act together to produce *radiant energy* in the form of electromagnetic waves. He defined visible light as a type of electromagnetic wave and predicted the existence of invisible waves. In the late 1880's, the German physicist Heinrich R. Hertz verified Maxwell's prediction. Hertz demonstrated that oscillation of an electric charge produces electromagnetic waves that are much longer than visible light waves. His discovery led to the development of radio and television. Gerald Feinberg

Related articles in *World Book* include:

Electromagnetism	Quantum field theory
Gamma rays	Radio (How radio programs are broadcast; diagrams)
Infrared rays	Ultraviolet rays
Light	X rays
Linear electric motor	
Microwave oven	

Additional resources

Inan, Umran S. and Aziz S. *Electromagnetic Waves.* Prentice Hall, 2000.

Skurzynski, Gloria. *Waves: The Electromagnetic Universe.* National Geographic Soc., 1996. Younger readers.

Electromagnetism is the branch of physics that studies the relationship between electricity and magnetism. Electromagnetism is based on the fact that (1) an electric current or a changing electric field produces a magnetic field, and (2) a changing magnetic field produces an electric field.

In 1820, the Danish scientist Hans Oersted discovered that a conductor carrying an electric current is surrounded by a magnetic field. When he brought a magnetized needle near a wire in which an electric current was flowing, the needle moved. Because a magnetized needle is moved by magnetic forces, the experiment proved that an electric current produces magnetism.

During the 1820's, the French physicist André Marie Ampère declared that electric currents produce all magnetism. He concluded that a permanent bar magnet has tiny currents flowing in it. The work of Oersted and Ampère led to the development of the *electromagnet,* which is used in such devices as the telegraph and the electric bell. Most electromagnets consist of a coil of wire wound around an iron core. The electromagnet becomes temporarily magnetized when an electric current flows through the wire. If the direction of the current changes, the poles of the electromagnet switch places.

Magnetism produces an electric current by means of *electromagnetic induction.* The English scientist Michael Faraday and the American physicist Joseph Henry discovered electromagnetic induction independently in the early 1830's. In electromagnetic induction, a changing magnetic field sets up an electric field within a conductor. For example, a magnet moving through a coil of wire causes the voltage to vary from point to point along the wire. An electric current flows along the wire as long as the magnetic field passing through the wire is changing. Electromagnetic induction is the basis of the electric generator. An electric motor reverses the process. A current sent through the wire causes the wire to move in a magnetic field.

In 1864, James Clerk Maxwell, a British scientist, used the earlier experiments to deduce that electric and magnetic fields act together to produce *electromagnetic waves* of *radiant energy.* The German physicist Heinrich R. Hertz proved Maxwell correct about 20 years later when he discovered electromagnetic waves.

Gerald Feinberg

Related articles in *World Book* include:

Electric generator	Electromagnetic waves
Electric motor	Magnetism (Electromagnets)
Electromagnet	Magnetometer

Electromotive force is a measure of the amount of work required to carry a unit of electric charge through a circuit. It is abbreviated as *emf* or *E.* The term also refers to the amount of potential energy obtained from an electric source per unit of charge passing through it. Such sources of electromotive force include batteries and electric generators. If 1 joule of electric potential energy is given to each coulomb of charge passing through the source, the emf of the source is 1 joule per coulomb, called 1 *volt.* See also **Coulomb; Electric current; Joule; Volt.** Robert B. Prigo

Electromotive series, also called the *electrochemical series* or *activity series,* is a listing of metals and hydrogen with respect to their tendency to lose electrons during chemical reactions. Metals that lose electrons more readily than hydrogen does are listed in the series before hydrogen. Those that lose electrons less readily than hydrogen follow hydrogen in the listing. The following is the order of some commonly used elements in the electromotive series: potassium, calcium, sodium, magnesium, aluminum, zinc, iron, nickel, tin, lead, hydrogen, copper, mercury, silver, platinum, gold.

Chemists use the electromotive series to predict how reactive a metal will be toward other materials. In general, the greater a metal's tendency to lose electrons, the more reactive it will be. Thus, metals that appear before others in the series tend to be more reactive than those that follow them. For example, a chemist would expect iron to react with oxygen more readily than gold does, because iron is listed before gold in the electromotive series. Iron reacts with oxygen in air to form rust, but gold does not. Gold maintains its shiny appearance in the presence of oxygen and is not corroded by it.

Lawrence L. Garber

Electron is a negatively charged subatomic particle. A useful model of an atom portrays it as a tiny nucleus surrounded by electrons. The electrons are at various dis-

tances from the nucleus and are arranged in energy levels called *shells.* Electrons occupy almost the entire volume of an atom but account for only a small fraction of an atom's mass. An atom's chemical behavior is determined largely by the number of electrons in its outermost shell. When atoms combine and form molecules, electrons in the outermost shell are either transferred from one atom to another or shared between atoms.

Ordinarily, an atom has an equal number of electrons and *protons,* positively charged particles found in the nucleus. Each electron carries one unit of negative charge, and each proton carries one unit of positive charge. As a result, the atom is electrically neutral. If an atom gains electrons, it becomes negatively charged. If it loses electrons, it becomes positively charged. Electrically charged atoms are called *ions.*

Electrons are fundamental units of matter—that is, they are not made up of smaller units. An electron's diameter is less than $\frac{1}{1000}$ the diameter of a proton (see **Proton**). An electron's mass in grams may be written with a decimal point followed by 27 zeros and a 9. Electrons are the lightest particles that have electric charges.

The discovery of the electron is generally attributed to Sir Joseph John Thomson, a British physicist who identified it in 1897. In 1913, the American physicist Robert A. Millikan reported an accurate measurement of the electron's charge. Edward S. Fry

Related articles in *World Book* include:

Atom	Ion	Muon
Dirac, Paul A. M.	Magnetism (Magnetism in atoms)	Subatomic particle
Electricity	Millikan, Robert A.	Thomson, Sir Joseph John
Electronics		

Electron microscope is a device that uses a beam of electrons to magnify an object's image. Electron microscopes can *resolve* (give clear pictures of) features much smaller than those visible through *optical microscopes,* which use lenses and visible light to magnify images. Tremendous magnifying power makes the electron microscope a major research tool in biology, chemistry, medicine, and metallurgy. Ernst Ruska and other German scientists built the first one in 1931.

In either an electron microscope or an optical microscope, the *wavelength* (distance between wave crests) of the beams that magnify the image limit the resolving power. An electron microscope can resolve smaller features because the electrons in its beams have a much shorter wavelength than do beams of visible light. The shortest wavelength of visible light is about 4,000 *angstroms.* One angstrom equals $\frac{1}{10}$ nanometer, or $\frac{1}{10,000,000}$ millimeter ($\frac{1}{254,000,000}$ inch). The electron beams used in most electron microscopes have wavelengths of less than 1 angstrom. There are two kinds of electron microscopes—*transmission* and *scanning.*

Transmission electron microscopes pass a beam of electrons through a specimen slice 100 or fewer nanometers thick. The specimen absorbs or scatters some electrons. Electrons that pass through the specimen are focused onto a fluorescent screen or photographic plate by electromagnets called *magnetic lenses.*

Scanning electron microscopes focus the electron beam so that it strikes a small spot on the specimen. The beam then *scans* the specimen in a regular pattern, just as a television picture is scanned (see **Television** [The television camera]). As electrons strike the specimen's surface, they throw off other electrons from it, called *secondary electrons.* The number of secondary electrons controls the intensity of another beam of electrons located inside a TV picture tube. This beam produces a magnified picture of the specimen on a TV screen.

Magnification. Transmission electron microscopes can magnify a specimen by 50 to 1,000,000 times. By contrast, optical microscopes can magnify objects up to 1,500 times. Scientists use transmission electron microscopes to view specimens as large as plant cells many micrometers across and as small as columns of atoms about 1.4 angstroms apart. The specimen appears to be flat because the electron beam passes through it. Scanning electron microscopes can magnify a specimen by 5 to 500,000 times. Specimens can be as large as fingerprints and as small as the fine details of a computer chip. Because secondary electrons originate on the specimen's surface, scanning electron microscopes produce sharp images of surface features. John B. Sharkey

See also the illustrations and diagrams on the next page; **Microscope; Scanning probe microscope.**

Electronic game. See **Video game.**

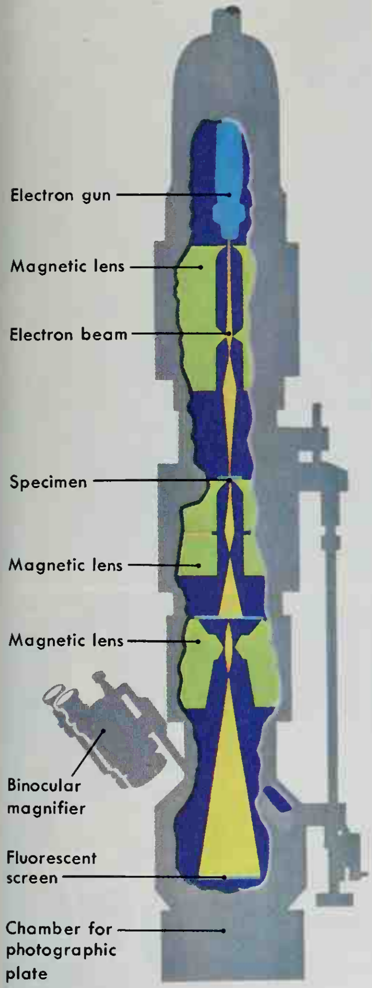
Electronic mail. See **E-mail.**

Electronic music is a kind of music in which sounds are produced electronically. Composers use electronic equipment to make sounds with a desired pitch, rhythm, loudness, and tone color. They assemble the sounds on magnetic tape or computer disks to create compositions and play them on a tape recorder through loudspeakers.

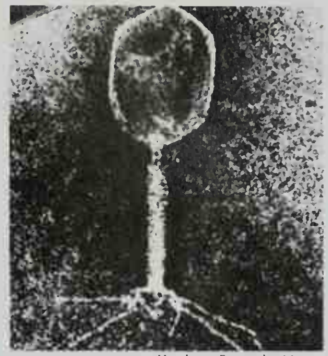
Many composers of electronic music use a machine called a *synthesizer* to combine, modify, and distort sounds. A synthesizer has several devices that change the pitch, tone, and amplitude of a sound. Synthesizers can imitate the sounds of traditional musical instruments but are more often used to create unique, new sounds. Synthesizers were invented because composers wanted to include a greater variety of sounds in their music than was possible with traditional instruments. Some composers use computers to do the work of synthesizers and tape recorders. Special computer programs can manipulate sounds like a synthesizer.

In the early 1900's, several people invented equipment that could produce electronic music. These inventors included Thaddeus Cahill in the United States, Maurice Martenot in France, and Leon Theremin in Russia. But electronic music did not begin to attract wide attention until the 1940's, when magnetic tape recorders came into general use. The first notable electronic music composer was Pierre Schaeffer of France, who worked exclusively with tape recorders and recordings of everyday sounds. Other major composers included Luciano Berio (Italy), Pierre Boulez and Edgard Varèse (France), Karlheinz Stockhausen (Germany), and Mario Davidowsky (United States). In the 1960's, several Americans, including Robert A. Moog and Donald Buchla, independently developed mass-produced synthesizers.

In its early days, electronic music caused much discussion among audiences and critics. Its supporters declared that electronic techniques increased the range of musical expression. Its opponents objected to the absence of any human element in performance. Some composers responded to objections by writing works in which performers interact with electronic instruments. Others developed computer programs that allow per-

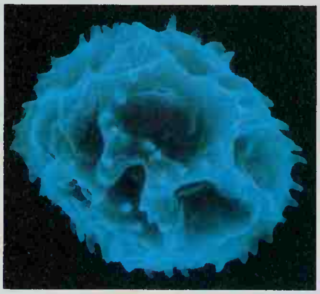


A transmission electron microscope passes electrons from an electron gun through the specimen to a fluorescent screen. A magnifier enlarges the image.



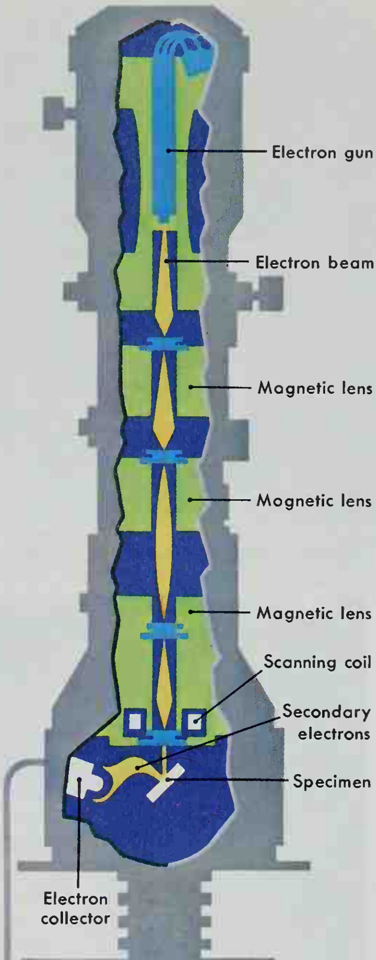
Humberto Fernandez-Moran, University of Chicago

A virus specimen appears flat in a transmission electron microscope because only a thin layer of it is in sharp focus. It is magnified 190,000 times.



Manfred Kage from Peter Arnold

A pollen grain of a dandelion has a rough surface that is visible with a scanning electron microscope. This grain is magnified more than 500 times.



WORLD BOOK diagrams

A scanning electron microscope moves electrons across the specimen with scanning coils. The electrons enter a collector and form a magnified image on a screen.

formers to shape computer output during a performance. These approaches permit the artist to interpret the composer's music. Mark D. Nelson

See also **Synthesizer; Stockhausen, Karlheinz; Varèse, Edgard.**

Electronic publishing is the use of computers to design, edit, and distribute material that traditionally would have been produced on printing presses. This material may be distributed on floppy disks or CD-ROM's (*C*ompact *D*isc *R*ead-*O*nly *M*emory), or sent out over the vast computer network called the Internet. In addition, publishers of printed books, magazines, and newspapers distribute electronic versions of many of their products.

Computers were first used in publishing for *computerized typesetting,* the production by computer of printed sheets of text called *galleys.* Next came *desktop publishing,* in which editors and designers used computers to edit text and lay out pages. The pages were then assembled partly on computer, but they were printed on presses. Today, publishers can complete every step in the production of books, magazines, newspapers, and other materials by electronic means. The material may even be distributed in electronic form.

Electronic publishing offers several advantages over print publishing. An electronic publication can use features that print cannot use, including animations, videos, and sounds. Electronic publications can be updated quickly and distributed almost instantly. In electronic publishing, space is much less limited than in print publishing. Printed material must often be edited to fit the number of pages available. But a standard CD-ROM can hold the equivalent of more than 250,000 pages of text. With Internet distribution, text length is a relatively minor concern. Much more important is the size of sound and visual files, which can take a long time to transmit to a computer. Keith Ferrell

See also **Desktop publishing; Publishing.**

Electronic surveillance. See Wiretapping.

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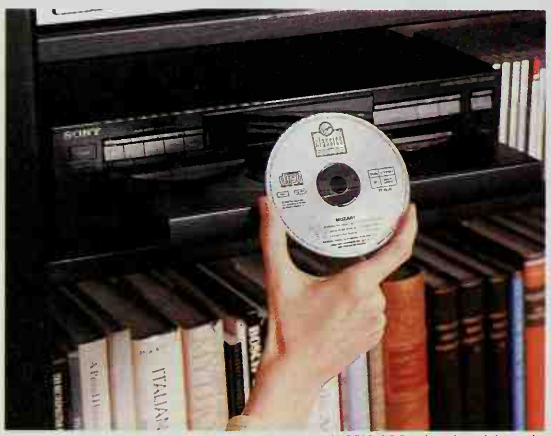
Scanning electron microscope with display screen

WORLD BOOK Information Finder

Electronic encyclopedia



WORLD BOOK photo by Ralph Brunke

Compact disc player

© David R. Frazier, Photo Researchers

Laser scanner at checkout counter

Electronics has revolutionized such fields as communications, education, medicine, entertainment, and business and industry. The photographs above and on the next page show some of the many uses of electronics.

Electronics

Electronics is a branch of physics and engineering that involves controlling the flow of electric charges in certain devices for a useful purpose. Electronic *components* (parts) are used in a broad range of products, including radios, television sets, computers, videocassette players, hearing aids, medical instruments, and many other products. Today, people rely so heavily on electronic products that the age we live in is often called the *electronic age.*

Thomas Edward Wade, the contributor of this article, is Professor of Electronics Engineering and Associate Dean for Research at the University of South Florida.

Electronics is part of the broad field of electricity. Electricity includes two important elements: (1) *electric current* and (2) *electric voltage.* Electric current is the flow of electric charges. Electric voltage is a type of "pressure" or force that causes the charges to move in the same direction. Familiar uses of electricity include the furnishing of energy in homes and businesses to provide light and heat, and to drive motors.

Electronics deals chiefly with the use of current and voltage to carry *electric signals.* An electric signal is an electric current or voltage modified in some way to represent information. A signal may represent sound, pictures, numbers, letters, computer instructions, or other information. Signals can also be used to count objects, to measure time or temperature, or to detect chemicals or radioactive materials.

Electronics depends on certain highly specialized

NASA

Johnson Space Center's Mission Control Center in Houston

components, such as transistors and integrated circuits, that serve as part of almost all electronic equipment. The value of such devices lies in their ability to manipulate signals extremely fast. Some components can respond to signals billions of times per second.

The field of *microelectronics* is concerned with the design and production of miniature components, chiefly integrated circuits, and of electronic equipment that uses such components. Manufacturers can create millions of microscopic electronic components on a piece of material—called a *chip*—that is no larger than a fingernail.

This article provides a broad overview of the basic tools and functions of electronics and the electronics industry. Separate *World Book* articles give detailed information on many of the topics. For a list of these articles, see the *Related articles* at the end of this article.

Uses of electronics

Electronics has changed the way people live. People have come to depend on electronic products in almost every part of their daily lives.

In communications. Electronic communication systems link people throughout the world. Radio can transmit a voice around the world in a fraction of a second. People in different countries communicate almost instantly through telephones and computers. A television viewer can watch events on another continent as they are taking place. Cellular telephones enable a person to call another person while riding in a car or walking down the street. Fax machines send and receive copies of documents over telephone lines in minutes.

Processing information. Electronic computers are used in business, schools, government, industry, scientific laboratories, and the home. People depend on computers to handle vast amounts of information with incredible speed and to solve complex mathematical problems in a fraction of a second. Online services provide computer users instant access to a wide variety of information and features through telephone lines.

Medicine and research. Physicians use a variety of electronic instruments and machines to diagnose and treat disorders. For example, X-ray machines use radiation produced in a special type of electronic vacuum tube to take pictures of bones and internal organs. Physicians analyze these pictures to detect injuries and diseases. Radiation therapy, or *radiotherapy,* uses X rays and other forms of radiation as a powerful weapon against cancer. Many hearing-impaired people depend on electronic hearing aids to *amplify* (strengthen) sound waves.

Computers and other electronic instruments provide scientists and other researchers with a clearer understanding of nature. For example, computers help scientists design new drug molecules, track weather systems, and test theories that describe how galaxies develop. Electron microscopes can magnify specimens by 1 million times.

Automation. Electronic controls improve the operation of many common home appliances, such as refrigerators, sewing machines, toasters, and washing machines. People can program coffeemakers, lawn sprinklers, and many other products to turn on and off automatically. Electronic devices control video games. Microwave ovens heat food quickly by penetrating it with short radio waves produced by a vacuum tube.

Industries use computers to control other machines. Electronic robots perform a wide variety of tasks that are boring, difficult, or dangerous for people. For example, some automobiles are painted by robots using spray paint that would harm people who breathed it.

Air, sea, and space travel depend on navigation by

radar, radio, and computers. Many automobiles have electronic controls in their engines and fuel systems. Also, electronic devices control the inflation of *air bags,* safety devices that inflate to protect a driver or a front-seat passenger in a head-on collision.

How an electronic system works

To provide a basis for understanding electronics, this section describes how a common product, a handheld electronic calculator, works. A calculator has a small keypad with keys for numbers and operations, and a display screen that shows results. Most calculators are powered by a small battery or by a panel of solar cells.

Beneath the keypad, tiny *circuits* operate the calculator. A circuit is a set of connected parts through which current flows. Pressing a key creates a pulse of electric charge representing a number or operation—in other words, a signal. The signals travel through wires to the circuits.

Each circuit has a job. Some circuits store signals temporarily, awaiting further instructions. Others change signals according to instructions. For example, a circuit might multiply two numbers together. Finally, circuits send signals that light up or darken certain areas on the display screen to show the result of a calculation.

The operations of a calculator, like most electronic systems, can be divided into three stages: (1) the *input* stage, in which information enters the system as signals; (2) the *processing* stage, in which the signals are manipulated in some way; and (3) the *output* stage, in which the processed signals are changed into a form that the user can understand. Systems use various types of input and output devices that produce or respond to signals. For example, radio and television broadcasting require such devices as microphones and loudspeakers. From the time signals leave the input device until they reach the output device, the signals can go through a number of changes. The electronic components working within circuits make these changes.

Electronic circuits

In any electronic device, a circuit provides a pathway for the electric current that operates the device. A calculator has a complex circuit. Many of the parts of this complex circuit are actually smaller subcircuits that perform particular jobs. Not all of the circuits necessarily work at the same time. Certain components act as electronic "switches," turning circuits "on" and "off" as needed. When a switch allows current to pass through a circuit, the circuit is on. When a switch blocks current, the circuit is off.

How a circuit works. To understand how an electronic circuit works, one must know something about atoms. Every atom has one or more *electrons*—particles that carry a negative electric charge. Atoms also contain *protons*—particles that carry a positive electric charge. Opposite charges attract each other. Like charges *repel* (push away from) each other. Circuit operation is based on the attraction between charges.

The flow of electrons in one direction at a time forms an electric current. Voltage, also known as *electromotive force,* is the "pressure" or force that drives the electrons. In circuits, voltage is the electrical attraction caused by the difference in the charges between two points in the circuit. A power source provides voltage. One side of the power source supplies a negative voltage, and the other end supplies a positive voltage. Batteries are a common power source. Systems that plug into an electric outlet receive power from a commercial power plant.

Electrons flow from the negative voltage end of a circuit to the positive voltage end. This movement of electrons creates an electric current. Scientists, however, traditionally describe the direction of an electric current

Terms used in electronics

Amplification is the strengthening of a weak signal.

Amplitude is the strength of a signal. Amplitude can be measured in terms of current, voltage, or power.

Binary code is used by computers to represent information. It consists of the 0's and 1's of the binary numeration system.

Charge carriers are electrons that can flow from atom to atom and so conduct electric current.

Conductor is a material that can carry an electric current.

Digital signals represent all information with a limited number of signals. Under the binary code, only two signals are used.

Diode is a component that blocks current from flowing through it in one direction but allows current to pass in the other.

Doping is the process of adding impurities to a semiconductor. The impurities, known as *dopants,* add positive or negative charge carriers to the material, thereby increasing its ability to conduct current.

Free electron is an electron that can move from atom to atom and so conduct electric current. Free electrons are also called *charge carriers.*

Frequency is the number of times a second that a signal vibrates—that is, changes its direction of flow.

Hole is the absence of an electron bond in a crystal.

Insulators are materials that block electric current.

Integrated circuit is a tiny *chip* (piece) of semiconductor material, usually silicon, that contains a complete electronic circuit. One integrated circuit can do the work of thousands of individual electronic components.

Logic gates are small groups of circuits designed to imitate a logic function, such as counting or comparing information.

Microprocessor is an integrated circuit that contains memory, processing, and control circuits on one chip.

Oscillation vibrates an electric signal to a desired frequency.

P-N junction is the area where a p-type semiconductor meets an n-type semiconductor within a continuous crystal.

Rectification changes alternating current into direct current.

Resistor is a circuit component that decreases current flow.

Semiconductor is a material that conducts electric current better than an insulator but not as well as a conductor. Semiconductors are important because their conductivity can be altered by doping and precisely controlled by signals.

Signal is an electric current or voltage modified to represent information, such as sound, pictures, or letters.

Solid-state components control a signal flowing through a solid semiconductor material.

Switch is a component that directs the path of a current. A switch can turn a circuit on or off.

Transistor is a component that uses a small signal to control a strong current. A transistor is an arrangement of p-n junctions that can be used to amplify a signal or switch a circuit on or off.

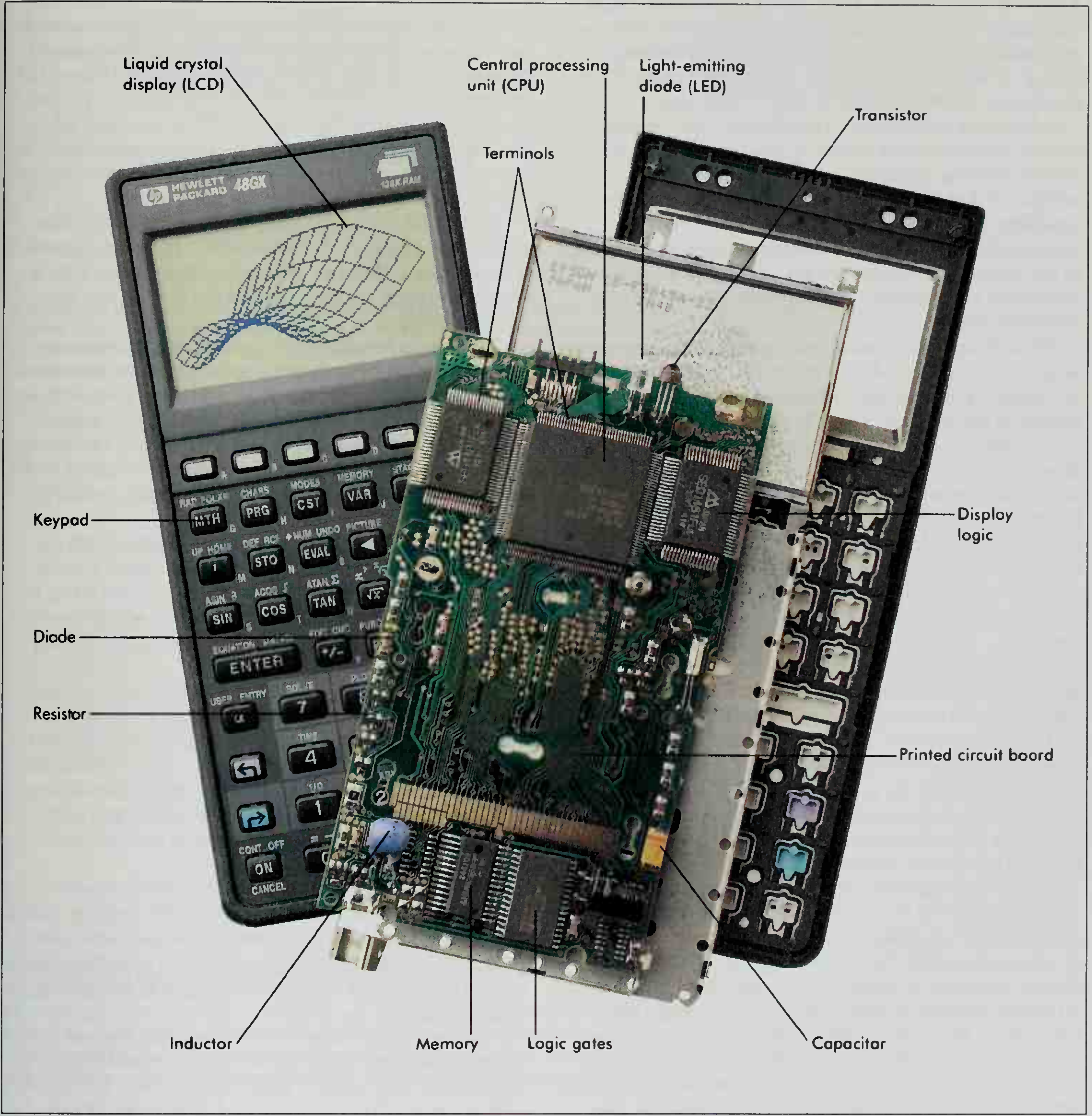
Vacuum tube is a component that controls a signal in a container from which most of the air has been removed.

Voltage is a type of "pressure" or force that drives charges through a circuit.

Parts of an electronic system

Many parts work together in the electronic system of the calculator below. The components are attached to a printed circuit board. Thin metal lines carry electric current between the parts. A chip called the *central processing unit* performs most calculations. It contains thousands of microscopic parts that form logic, memory, and control circuits. Other chips help process signals. Individually made components, such as transistors, diodes, and resistors, direct and control the current.

Hewlett Packard



as flowing from positive to negative. Until the late 1800's, scientists mistakenly believed that an electric current flowed in that direction.

Wires and certain other parts of circuits are made of materials called *conductors,* which can carry an electric current. In conductors, which include metals, each atom has one or more electrons that can move from atom to atom. These electrons are called *free electrons* or *charge carriers.* Circuits also contain *insulators,* materials that block current because they have no mobile charge carriers.

As electrons move through a conductor, they collide with the atoms of the material. Each collision hinders the flow of electrons and causes them to lose some energy as heat. Opposition to electric current, which changes electric energy into heat, is known as *resistance.*

A build-up of heat can damage a circuit. A calculator uses so little current that there is no danger of overheating. However, some computers generate so much heat that their circuits must be continually cooled. The whirring noise a desktop personal computer makes comes from a small fan that cools the system.

Types of electronic circuits. Manufacturers make two types of electronic circuits: (1) conventional and (2)

integrated. A calculator, like most electronic devices, has both kinds.

Conventional circuits consist of separate electronic components connected by wires and fastened to a base. In most cases, manufacturers attach the components to a *printed circuit board,* a thin piece of plastic or other insulating material upon which copper "wires" are printed by a chemical process at the time of manufacture. In a calculator, all the electronic parts of the main circuit are connected on a printed circuit board.

Integrated circuits have components and connectors formed on and within a chip—a tiny piece of *semiconductor* material, usually silicon. A semiconductor is a substance that conducts electric current better than an insulator, but not as well as a conductor. The chip serves not only as the base but also as an essential part of the circuit. Most chips are no larger than a fingernail. Integrated circuits often serve as components of conventional circuits.

To make an integrated circuit, a technician prepares a large master design of the circuit with the help of a computer. A photographic process reduces the master design to microscopic size. Chip manufacturers treat silicon to alter its conductive properties by adding small amounts of substances called *dopants,* such as boron and phosphorus. The treated regions form the chip's electronic components. One chip can contain millions of microscopic parts connected by thin "lines" of metal. Chip makers arrange the parts and connections in complex patterns in several layers. Finished circuits are mounted in casings that plug into a printed circuit board.

The small size of an integrated circuit gives it several advantages over a conventional circuit. For example, an integrated circuit works faster because the signals have less distance to travel. Integrated circuits also need less power, generate less heat, and cost less to operate than conventional circuits. In addition, integrated circuits are more reliable because they have fewer connections that might fail. But strong currents and high voltages can damage integrated circuits because of their small size.

A type of integrated circuit called a *microprocessor* can perform all of the mathematical functions and some of the memory functions of a large computer. Microprocessors control many products, including video games, microwave ovens, robots, and some telephones. A microprocessor serves as the "brain" of every personal computer. Larger computers have several microprocessors that can work together at the same time.

Electronic devices use two basic types of components within circuits to control and modify signals. The two types are (1) electron tubes and (2) solid-state devices.

Electron tubes

Electron tubes control the flow of electric signals through a gas or a near-vacuum. *Vacuum tubes* are the most common type of electron tube. A vacuum tube is a glass or metal container from which most of the air has been removed. Various metallic elements within the tube produce and control beams of electrons.

From the 1920's to the 1950's, all electronic equipment used vacuum tubes. Some equipment still uses special types of such tubes. For example, the screen of a typical TV set is the end of a large vacuum tube called a *cathode-ray tube.* Other types of vacuum tubes produce radio and radar signals, X rays, and microwaves. For more information about the various kinds of vacuum tubes and how they work, see **Vacuum tube.**

Solid-state components

Transistors and certain other electronic components are called solid-state components because the signals flow through a solid semiconductor material instead of through a vacuum. Solid-state devices use less power, last longer, and take up less space than vacuum tubes. Engineers developed the first successful solid-state devices during the 1940's. Since that time, semiconductors have replaced vacuum tubes for most uses.

Most solid-state components are made of the semiconductor silicon. Silicon and other similar semiconductors are useful because scientists can precisely adjust their resistance and thus control the flow of current through them.

To be used for electronic devices, the atoms of a semiconductor must form a crystal structure. In these crystals, each of an atom's outer electrons pairs with an outer electron of a neighboring atom to form linkages known as *electron bonds* or *covalent bonds.* Ordinarily, the outer electrons are tightly bound to the atoms of the crystal, and the material acts as an insulator, resisting the flow of charges.

Scientists *dope* (treat) pure silicon crystals with extremely small amounts of dopants to increase the silicon's ability to conduct current. There are two types of doped semiconductors: (1) p-type, which contain mostly *p*ositive charge carriers; and (2) n-type, which contain mostly *n*egative charge carriers.

To create p-type semiconductors, scientists add dopants whose atoms have one less outer electron than a silicon atom. Aluminum, boron, indium, and gallium are p-type dopants. Each impurity atom creates a *hole*—that is, the absence of an electron bond—in the crystal structure. A hole acts as a positive charge, attracting electrons from neighboring atoms. Thus, a hole can move from atom to atom.

To create n-type semiconductors, scientists add dopants whose atoms have one more outer electron than a silicon atom. Arsenic, phosphorus, and antimony are n-type dopants. At room temperature, the extra electron is free to move within the crystal and acts as a negative charge carrier.

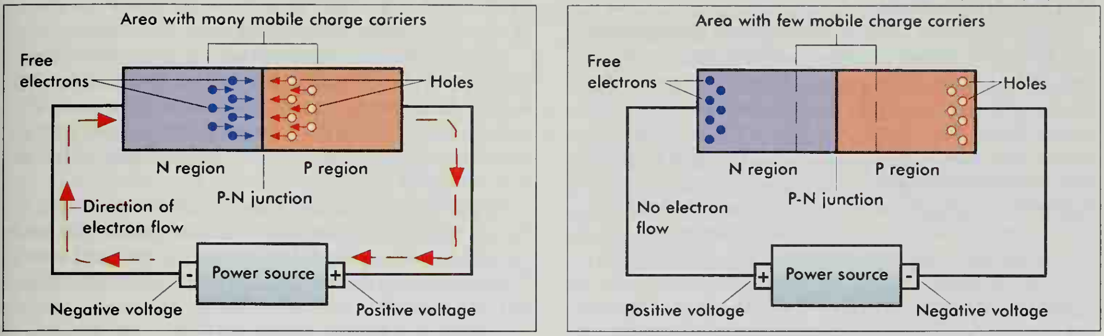
Manufacturers make various electronic devices by forming different combinations of p-type and n-type semiconductors within a continuous crystal. The place where the two types of semiconductors meet is called a *p-n junction.* The number and arrangement of p-n junctions, as well as the type and amount of dopants, determine how a device works.

Diodes are electronic components that prevent current from flowing in one direction but not the other. A semiconductor diode consists of a piece of p-type semiconductor joined to a piece of n-type semiconductor. A diode has two *terminals* (metal parts for making electrical connections). The terminals connect the end of each type of semiconductor material to the circuit. A diode can be built into an integrated circuit, or can form a *discrete* (separate) component of a conventional circuit. A discrete diode is enclosed in a protective casing.

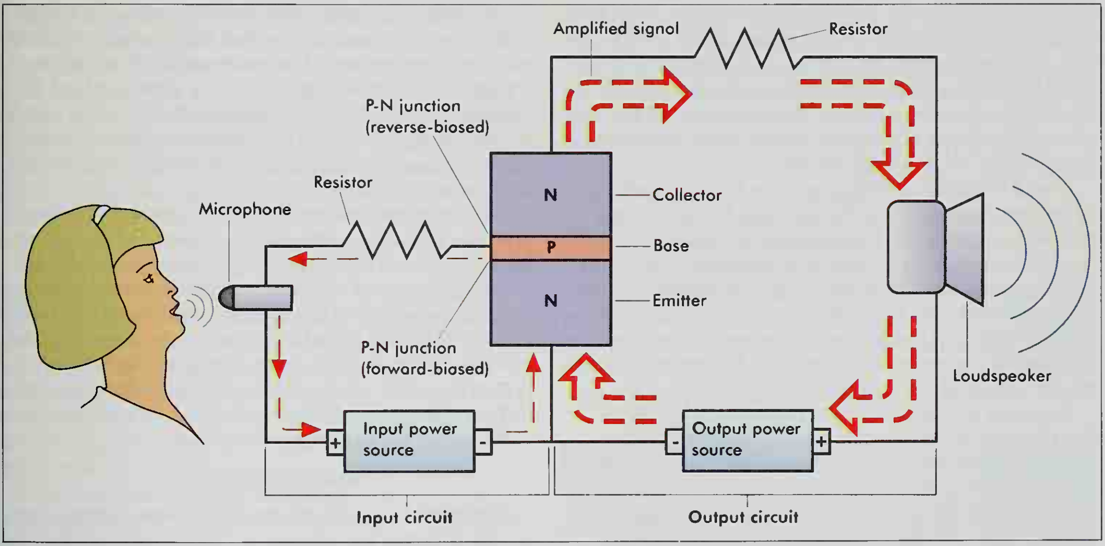
How semiconductor components work

All semiconductor active components contain at least one *p-n junction.* The number of charge carriers near the junction determines if a current can flow through the junction. What a component does depends on how many junctions it has and how the circuit is arranged.

WORLD BOOK illustrations by Garri Budynsky, Artisan



A diode has one p-n junction that can either conduct or block current, depending on the *bias* (direction) of a voltage applied to the diode's two terminals. A forward-biased diode, *left,* conducts current because charge carriers are attracted toward the junction. A reverse-biased diode, *right,* blocks current because charge carriers move away from the junction.



An amplifying transistor circuit can strengthen a voice signal. *Above,* a bipolar junction transistor is connected to an input circuit and an output circuit. A microphone picks up sound waves and changes each wave into a voltage signal. The voltage is applied across the transistor's forward-biased junction. As a result, free electrons from the emitter enter the base, overcoming the ability of the reverse-biased junction to block current. A strong current—fluctuating according to the pattern of the sound waves—flows through the output circuit and operates the loudspeaker.

How a diode works. A diode is basically a switching device that allows current to flow in only one direction. The current is carried by the flow of holes and electrons. The *bias* (direction) of the applied voltage determines if the p-n junction blocks current or allows it to flow.

A *forward bias* allows current to flow through the junction. To create a forward bias, a battery or other voltage source applies a negative voltage to the n-type material and a positive voltage to the p-type material. The negative voltage repels the free electrons in the n-type material toward the p-n junction. Likewise, the positive voltage repels the holes in the p-type material toward the junction. The electrons move across the junction into the p-type semiconductor. For each electron that crosses into the p-type material, the voltage source pumps one electron into the n-type material and pulls one electron out of the p-type material. As a result, electrons flow through the circuit. A small increase in the strength of the voltage causes a large increase in the current flowing through the diode. When the voltage is removed, electron flow stops.

A *reverse bias* prevents most current from flowing through the p-n junction, though a small *leakage current* gets through. To create a reverse bias, a voltage source applies a negative voltage to the p-type semiconductor and a positive voltage to the n-type semiconductor.

As a result, holes and electrons are attracted away from the junction. This creates an area on either side of the junction with no mobile charge carriers. The junction area acts as an insulator.

Uses. Diodes are used as switches and also as *rectifiers.* A rectifier circuit can change *alternating current* into *direct current.* Alternating current reverses its direction of flow many times each second. Direct current always flows in the same direction. A terminal connected to a source of alternating current gets a voltage that constantly changes from positive to negative and back again. If an alternating current is sent to a diode, the device will pass current only when the n-type semiconductor has a negative voltage. Thus, current flows through the diode in only one direction.

Almost all commercial power plants supply alternating current. Most electronic equipment requires direct current. Devices that run on commercial power use diodes as rectifiers. Devices powered by batteries do not need rectifiers because batteries produce direct current.

Transistors are arrangements of p-n junctions that can be used to amplify signals or switch a circuit on and off. Just as a small movement of a mechanical switch can turn a powerful motor on and off, a transistor uses a small input signal to control the flow of a strong current. A transistor can turn a current all the way on, all the way off, or partially on. Transistors are the most important components of integrated circuits.

How a transistor works. There are several types of transistors that work in different ways. One important type is the *bipolar junction transistor* or *bipolar transistor.* The component consists of an extremely thin layer of one type of semiconductor sandwiched between two thicker layers of the opposite type. For example, if the middle layer is n-type, the outer layers must be p-type. The middle region is called the *base.* The outer regions are the *emitter* and the *collector.*

A bipolar junction transistor has two p-n junctions and three terminals. Usually, two of the terminals connect the emitter and collector to an output circuit. The third terminal connects the base to an input circuit. Each circuit has a power source. The power sources are arranged so that one p-n junction is forward biased and the other junction is reverse biased.

Normally, the transistor prevents current from flowing through the output circuit. However, a small increase in voltage on the base terminal enables a large number of electrons to enter the base through the forward-biased junction. The number of electrons entering the base varies with the strength of the voltage. Because the base region is extremely narrow, the voltage source in the output circuit is able to attract the electrons through the reverse-biased junction. As a result, a large current flows through the transistor and through the output circuit. In this way, a small signal supplied to the base controls the flow of a strong current through the output circuit.

Another major type of transistor is the *field effect transistor,* which works in a different way than the bipolar transistor. For more information on both types of transistors and how they work, see **Transistor.**

Uses. Transistors perform three main electronic functions: (1) amplification, (2) switching, and (3) oscillation.

Amplification is the strengthening of a weak, fluctuating signal. The current that flows through the transistor and the output circuit is basically a duplicate of the input signal—but much stronger. A transistor can react to signal fluctuations billions of times per second.

Most electronic equipment would not work without amplifiers. Amplifiers are used in equipment designed to transmit or process *audio* (sound) or *video* (picture) signals. Most signals must be amplified so that they can drive an output device, such as a loudspeaker, a TV set, or a computer printer.

Amplifiers are also used to detect information. For example, special instruments record and amplify the weak electric signals given off by the human heart and brain. Physicians study these signals to diagnose certain injuries and diseases.

Switching is another important function of a transistor. As a switch, a transistor turns a circuit on or off or directs the path of signals. For a transistor to function as a switch, the strength of input signals must vary widely, so that the transistor simply turns the main supply current all the way on or off.

Oscillation converts a direct current signal to an alternating current signal of a desired *frequency* (number of vibrations per second). Transistor circuits that do this are called *oscillators.* An oscillator is actually a kind of amplifier that strengthens a signal and then feeds part of the amplified signal back into itself to produce its own input. Various circuit arrangements enable a transistor to act as an oscillator.

Oscillators serve many purposes. For example, they produce the radio waves that carry sound and pictures through space. They also produce timing signals that control the internal operations of computers and that operate certain types of automatic machinery. In medicine, an oscillator called a *cardiac pacemaker* produces carefully timed electric pulses similar to the natural pulses that make the heart beat regularly. Surgeons implant cardiac pacemakers inside the chest of certain patients to correct an irregular heartbeat.

Passive components

Electronic components may be divided into two categories: (1) active and (2) passive. *Active components* are those that can amplify, switch, or oscillate signals. Most electronics experts classify electron tubes, transistors, and certain diodes as active components. *Passive components* either change electric energy into heat or store electric energy internally. Passive components include *resistors, capacitors,* and *inductors.*

Resistors change electric energy into heat. Resistors are used to reduce the amount of current flowing through a circuit. The larger the resistor, the smaller the amount of current that flows through it.

Capacitors and inductors store electrical energy. Electronic circuits use capacitors to store information as the presence or absence of a charge. Capacitors are also used to block the flow of a direct current. Inductors, on the other hand, block the flow of alternating current but allow direct current to pass. See **Capacitor; Inductance.**

In integrated circuits, manufacturers can adjust the semiconductor chip to create areas that act as resistors and capacitors, but not as inductors. Inductors can be created only through complex circuitry. Inductors can

also be attached to integrated circuits as discrete components.

Electronics and light

Many electronic devices make use of the ability of electrons to absorb and give off energy as light. Such *optoelectronic devices* include light-sensing devices, light-emitting devices, and liquid crystal displays.

Light-sensing devices, also known as *electric eyes,* use light energy to produce or control an electric current. The heart of such devices consists of a light-sensing diode, or *photodiode,* usually made of silicon. A photodiode resembles an ordinary diode but has a window or lens that lets light fall onto the p-n junction. The light knocks some electrons out of their crystal bonds, producing pairs of free electrons and holes that can flow. Some photodiodes, such as *solar cells,* generate current. Panels of solar cells power most artificial satellites and many smaller electronic devices, such as calculators. Other photodiodes are used to switch an external power supply on and off. See **Light** (diagram: Photoelectric effect of light).

Light-emitting devices use electric current to produce light. Most *light-emitting diodes* (LED's) are made from gallium arsenide or other semiconductor compounds that give off energy in the form of light instead of heat. As current flows through an LED, free electrons and holes near the p-n junction combine. When a free electron "falls" into a hole, the process releases a tiny packet of light energy called a *photon.* With a strong enough current, the junction area of the chip glows brightly. Groups of LED's are used in many displays.

Semiconductor lasers are special diodes that produce an extremely narrow, powerful beam of light. Lasers have many uses in communications, industry, medicine, and science. For example, with fiber-optic communication, a laser beam transforms the electric signals of a telephone call or TV picture into pulses of photons. The photon signals travel at great speeds through hair-thin strands of glass called *optical fibers* without losing much strength or clarity.

Liquid crystal displays (LCD's) are commonly used in calculators, digital watches, and laptop computers. A thin layer of liquid crystal is sandwiched between two sheets of glass. Normally, the display reflects light. A voltage signal causes portions of the display to darken. These portions form the shape of a number or letter. See **Liquid crystal.**

How electronic circuits process information

Circuits process information by combining inputs to produce new information according to instructions. The way a circuit processes information depends on the type of signals it works with.

Electronic circuits work with two basic types of signals: (1) digital and (2) analog. Digital signals represent all information with a limited number of voltage signals. Each signal has a distinct value. Analog signals vary continuously in voltage or current, corresponding to the input information. A fluctuating voltage can stand for changes in light, sound, temperature, pressure, or even the position of an object.

Digital circuits process information by counting or comparing signals. Many digital circuits can process information much faster than analog circuits. The majority of processing is done by digital circuits.

In digital processing, all input data—words, numbers, and other information—are translated into *binary* numbers, which are groups of 1's and 0's. The code is called *binary* (consisting of two) because only two digits are used. Any binary number can be represented by a combination of circuits or devices that are in one of two states. For example, a circuit can be on or off. One state corresponds to a binary 1 and the other to a 0. Each 1 or 0 is called a *bit,* a contraction of *bi*nary digi*t.* Many systems work with bits in groups called *words.* A word that consists of 8 bits is called a *byte.*

Digital processing requires three basic elements: (1) *memory circuits,* which store data; (2) *logic circuits,* which change data; and (3) *control circuits,* which direct the operations of the system. Wire channels called *buses* link the elements to each other as well as to the entire system. A microprocessor combines these elements on one chip.

Memory circuits store bits permanently or temporarily. A common type of memory circuit contains thousands of capacitors arranged in rows. The capacitors hold bits as an electric charge or the absence of a charge. A metal conductor connects each capacitor to the system. Transistors or diodes act as switches between the capacitors and conductors. When a signal opens a switch, bits can travel along the conductor. Other circuits then restore the bits by recharging the capacitors with the same sequence of charges.

There are two basic kinds of memory circuits—*random-access memory* (RAM) and *read-only memory* (ROM). The information in RAM can be erased or added to. RAM circuits store data only as long as the power is on. When the power is turned off, all the stored charges are wiped out. RAM circuits are used in such devices as computers and certain calculators, which need to store large amounts of information for brief periods.

Intel Corporation

A researcher at an electronics laboratory wears special clothing designed to help protect the tiny silicon chips being tested. A single particle of dust can damage the chips.

A ROM circuit permanently stores information installed at the time of manufacture. This information can be neither erased nor added to. ROM generally contains instructions, or *programs,* for operating the system.

Not all memory is stored in circuits. For example, computers also use external memory devices, such as magnetic disks and magnetic tapes. Users input such memory into the system. A *compact disc,* another type of memory device, stores information on a plastic platter. Compact discs called *CD-ROM's* and *DVD's* can store data, pictures, and sound as well as programs.

Logic circuits, also called *processors,* manipulate data according to instructions. In a processor, the bits go through a sequence of switches that change them in some way. For example, a group of switches may add two numbers together. Such a group is called an *adder.* An adder may involve hundreds of switches. During processing, bits are stored temporarily in areas called *registers,* awaiting the next instruction.

Another combination of switches can compare two bits and generate a particular output based on a set of rules established for the processor. Such circuits use binary digits to stand for such ideas as "true" or "false," instead of 1 or 0.

Designers create areas on chips that can count or compare signals by combining small groups of circuits that make simple changes in just one or two bits. These groups are often called *logic gates.* Three basic gates are (1) the *NOT-gate,* (2) the *AND-gate,* and (3) the *OR-gate.* If combined in large enough numbers, these gates can solve complex mathematical or logical problems.

A NOT-gate, also called an *inverter,* changes a bit from a 1 to a 0, or from a 0 to a 1. Such a function has many uses. For example, addition involves changing 0's to 1's and 1's to 0's.

Both AND- and OR-gates generate one output signal from two or more inputs. An AND-gate requires that all inputs be true—often represented by a 1—to produce a true output, or a 1. An OR-gate requires only one true input to produce a true output.

Control circuits direct and coordinate the work of all other parts of the system according to instructions stored in the memory circuits. One of the main jobs of the control circuit is to control the movement of bits through the system. To do this, an oscillator called the *clock* generates continuous pulses. The bits move through the circuit according to the rhythm of the clock.

Analog circuits solve problems by measuring continuously varying quantities, such as temperature, speed, and pressure. Many familiar devices, including speedometers and thermometers, work as analog computers. Small analog circuits are parts of many electronic systems that control the operations of other machines. Analog circuits are also used in navigation equipment. For more information on analog processing, see **Analog computer.**

Digital-analog conversion. Some circuits can convert analog signals into digital signals, and digital into analog. In digital sound recording, for example, the *amplitude* (strength) of the sound wave is measured thousands of times every second and converted into a digital code signal made up of rapid bursts of current. To play the resulting digital signals, a sound system converts them back to analog signals that drive a loudspeaker. Digital signals produce better sound quality with less background noise and distortion than analog signals.

The electronics industry

The development, manufacture, and sales of electronic products make up one of the largest and most important industries in the world. The electronics industry is also one of the fastest-growing of all industries.

Research and development. Engineers and scientists at research laboratories work to add new knowledge about electronics and to develop new electronic devices. In the United States, a number of universities and electronics companies maintain research laboratories. In 1982, many large manufacturers and users of computer chips formed a nonprofit organization called the Semiconductor Research Corporation to support basic research on electronics at universities.

The U.S. government sponsors electronics research through such agencies as the National Science Foundation, the National Aeronautics and Space Administration, and the Department of Energy. The government also sponsors research through its military branches. In addition, the electronics industry and the government combine research efforts through the Semiconductor Manufacturing Technology Institute, better known as SEMATECH. The government and 14 electronics companies founded SEMATECH in 1987 to help U.S. chip makers become more competitive in manufacturing.

Manufacturing and sales. The United States and Japan are the world's largest producers of electronic components and assembled electronic products. In the mid-1990's, electronics companies in the United States employed more than 1 $\frac{1}{2}$ million workers. The sales of these companies totaled more than $250 billion. During the same period, electronics companies in Japan employed about 1 $\frac{1}{4}$ million workers. The Japanese firms had total sales valued at more than $200 billion in U.S. dollars. Other leading producers of electronic equipment include Canada, Germany, the Netherlands, Singapore, South Korea, Taiwan, and the United Kingdom.

Careers in electronics can be divided into two main groups. They are (1) engineering and scientific careers and (2) technical careers.

Engineering and scientific careers range from developing new electronic devices to designing computers. Most of these careers require a college degree in engineering or physics. The *World Book* articles on **Engineering** and **Physics** discuss the requirements for becoming an electrical engineer and a physicist.

Most engineers and physicists who specialize in electronics work for electronics companies. Some of these companies do most or all of their work on military projects. Other engineers and physicists find jobs with the federal government, at colleges and universities, and in communication, medicine, or transportation.

Technical careers in electronics usually involve installing, operating, maintaining, or repairing electronic equipment. Many technical jobs require training in a trade school or community college. Such technical careers include automation control, computer programming, television repair, and X-ray technology.

Other technical jobs require only on-the-job training. Such jobs include operating certain types of electronic equipment in factories and offices. Some highly skilled

technical jobs in the aerospace and communications industries require a college degree. Many people receive technical electronics training in the armed forces.

The development of electronics

Early experiments. During the mid-1800's, scientists experimented with *gas-discharge tubes*—that is, tubes from which some of the air had been removed, leaving a thin mixture of gases. Most of these tubes contained a combination of such gases as hydrogen and nitrogen at low pressure. Scientists discovered electric current could pass through the gas from one metal *electrode* (terminal) to another. When a battery was connected to the two electrodes, the tube glowed with bright colors. Scientists believed that the *cathode*—the negative electrode—gave off invisible rays that caused the colors. They named the rays *cathode rays.* As scientists removed still more air from the tubes for their experiments, the tubes became vacuum tubes.

In 1879, Sir William Crookes, a British scientist, developed a tube to study cathode rays. The Crookes tubes were forerunners of television picture tubes.

In 1895, the German physicist Wilhelm C. Roentgen discovered X rays while studying cathode rays in a Crookes tube. By the end of the 1800's, many doctors were using X-ray photographs to diagnose internal diseases and injuries in their patients.

In 1897, the British physicist Joseph J. Thomson proved that cathode rays consist of negatively charged particles, later named *electrons.* Thomson's discovery led to the first practical electronic devices.

During the early 1900's, electrical engineers developed vacuum tubes that could detect, amplify, and create radio signals. In 1907, the American inventor Lee De Forest patented a three-electrode, or *triode,* vacuum tube. The triode tube became a key element in radio broadcasting and reception because it could amplify signals. Commercial radio broadcasting began in 1920, and the electronics industry was born. By 1927, more than 5 million American homes had radios.

The vacuum tube era lasted from the 1920's to the 1950's. During this period, vacuum tubes made possible such electronic inventions as television, radar, and computers.

As early as 1875, the American scientist G. R. Carey had built a *photoelectric cell,* a device that produced an electric current when light shone on it. Carey's invention operated on the same principle as a TV camera, but it was not put to practical use until the early 1920's. In 1923, a Russian-born American scientist named Vladimir K. Zworykin made the first successful television camera tube. Using a cathode-ray tube as a model, Zworykin also developed a workable television picture tube during the 1920's. Experimental telecasts began in the late 1920's, but TV broadcasting did not begin on a large scale until the late 1940's.

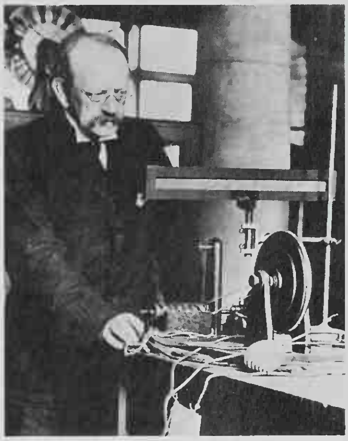
In 1921, Albert W. Hull, an American engineer, invented a vacuum tube oscillator called a *magnetron.* The magnetron was the first device that could efficiently produce microwaves. Radar, which was developed gradually during the 1920's and 1930's, provided the first widespread use of microwaves.

The vacuum tube era reached its peak with the completion of one of the earliest general-purpose electronic digital computers in 1945. This huge machine, called ENIAC (*E*lectronic *N*umerical *I*ntegrator *A*nd *C*omputer), was built by two engineers at the University of Pennsylvania, J. Presper Eckert, Jr., and John W. Mauchly. The computer contained about 18,000 vacuum tubes and occupied about 1,800 square feet (170 square meters) of floor space. ENIAC worked 1,000 times faster than the fastest nonelectronic computers then in use.

The solid-state revolution. Three American physicists—John Bardeen, Walter H. Brattain, and William Shockley—invented the transistor in 1947. Transistors revolutionized the electronics industry, dramatically reducing the size of computers and other equipment. Transistors were used as amplifiers in hearing aids and pocket-sized radios in the early 1950's. By the 1960's, semiconductor diodes and transistors had replaced vac-

Brown Bros.

The Crookes tube was developed in 1879 by Sir William Crookes, *shown here.* The tube produced cathode rays. It became a model for TV picture tubes.



Brown Bros.

The electron was discovered in 1897 by Joseph J. Thomson, *shown here.* The discovery led to the first practical electronic components.

Brown Bros.

The vacuum tube amplifier was patented in 1907 by Lee De Forest, *shown here.* This tube led to the development of the radio industry.

ENIAC, one of the first general-purpose electronic digital computers, was completed in 1945. John W. Mauchly, *center,* and J. Presper Eckert, Jr., *front left,* invented the huge machine.

UPI/Bettmann Newsphotos

uum tubes in many types of equipment.

Integrated circuits developed from transistor technology as scientists sought ways to build more transistors into a circuit. The first integrated circuits were patented in 1959 by two Americans—Jack Kilby, an engineer, and Robert Noyce, a physicist—who worked independently. Integrated circuits caused as great a revolution in electronics in the 1960's as transistors had caused in the 1950's. The circuits were first used in military equipment and spacecraft and helped make possible the first human space flights of the 1960's. They were soon being used in household electronics products, such as sewing machines, microwave ovens, and television sets.

The first microprocessors were produced in 1971 for desktop calculators. By the mid-1970's, microprocessors were being used in handheld calculators, video games, and home appliances. Business and industry began to use microprocessors to control various types of office machines, factory equipment, and other devices.

The digital age. In the 1980's and 1990's, many products began to take advantage of digital technology. Personal computers became commonplace in the home. Digitally recorded music became available on compact discs. Manufacturers introduced the *DVD,* a disc of the same size as a compact disc, but which can hold many times more information. According to most DVD manufacturers, the letters "DVD" have no specific meaning. A single DVD can hold a complete motion picture, with better picture quality than magnetic videotape.

In the 1990's, communication systems that use digital technology gained in importance. For example, digital television systems improve TV pictures by enabling television signals to carry more information. Digital TV uses a technique called *data compression* to remove unnecessary information from the signal. One type of digital television—*high-definition television* (HDTV)—provides a picture about four times as sharp as standard television does. Limited HDTV broadcasts began in Japan in 1996 and in the United States in 1998.

Electronics today. Scientists and engineers continue to search for ways to make electronic circuits smaller, faster, and more complex. Developing technologies include superconductors and photonics.

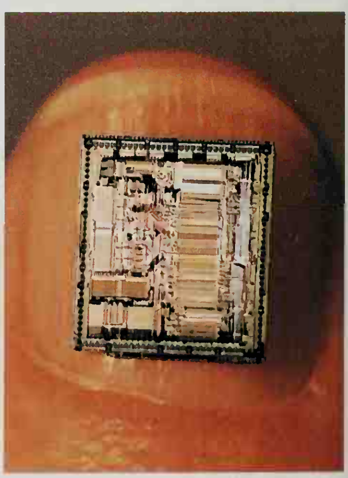
Superconductors are materials that lose all resistance to the flow of current at low temperatures. Superconductor devices operate extremely fast and produce al-

RCA

Vladimir K. Zworykin developed the TV camera tube and picture tube during the 1920's.

Bell Laboratories

The transistor was invented in 1947. Its inventors were William Shockley, *seated,* Walter H. Brattain, *left,* and John Bardeen, *right.* Transistors greatly reduced the size of electronic equipment.



Thomas Edward Wade

The microprocessor was first developed in the 1970's. This tiny, powerful chip can perform most of the functions of a large computer.

WORLD BOOK photo by Jeff Guerrant

The miniaturization of electronics has brought about the development of such small computing devices as this *personal digital assistant,* or PDA. To use some PDA's, a person uses a pencil-like stylus to write directly on a touch-sensitive screen.

most no heat. Scientists are testing superconducting switching devices to control computer circuits.

Photonics is the science of building circuits that use photons—tiny packets of light energy—as signals instead of electrons. Photonic circuits use pulsed beams of photons to transmit data and commands through optical fibers. Photonic circuits can carry huge amounts of information, and they produce no heat. Today, the enormous information-carrying capacity of optical fibers is opening a new era in home entertainment, communications, and computer technology.

Display techniques in electronics are also rapidly changing. Manufacturers are developing flatter display panels to replace the bulky cathode-ray tubes used in television and many computer screens.

One type of flat-panel display, called a *liquid crystal display,* or *LCD,* uses *liquid crystals*—molecules that display colors when activated by electric signals. LCD panels have a very low power consumption. They are used in portable computers and electronic games. A special type of LCD, called a *thin-film transistor active-matrix LCD,* provides a much brighter display. In such displays, thousands of transistors on the screen's inner surface control the signals that activate the liquid crystals.

Another type of flat-panel display, called a *plasma display,* uses a layer of gas between two glass panels. An electric current passed through the gas ionizes it, producing ultraviolet light that excites red, blue, and green chemicals called *phosphors* on the surface of the glass. Another display type, called a *field emission display,* or FED, uses thousands of tiny vacuum tubes side by side to form a picture. The principle of the FED is similar to that of the cathode ray tube of a conventional television set, but with a much greater number of tubes. The display provides a brighter picture and uses less power than LCD displays. Thomas Edward Wade

Related articles in *World Book* include:

Biographies

Armstrong, Edwin
Bardeen, John
Brattain, Walter H.
De Forest, Lee
Eckert, J. Presper, Jr.
Kilby, Jack
Roentgen, Wilhelm C.
Shockley, William
Thomson, Sir Joseph J.
Zworykin, Vladimir K.

Electronic components

Capacitor
Computer chip
Crookes tube
Electrode
Iconoscope
Image orthicon
Photomultiplier tube
Semiconductor
Transistor
Vacuum tube

Uses of electronics

Airport (Air traffic control)
Automated teller machine
Automation
Bank (Electronic banking)
Biomedical engineering
Calculator
Camcorder
Camera (Digital cameras)
Cellular telephone
Compact disc
Computer
Computed tomography
Digital technology
DVD
Electric eye
Electrocardiograph
Electroencephalograph
Electron microscope
Electronic music
Hearing aid
Laptop computer
Laser
Light meter
Lock (Electronic locks)
Magnetic resonance imaging
Maser
Microwave oven
Navigation (Electronic navigation)
Organ (Electronic organs)
Oscilloscope
Phonograph
Printer
Printing (Digital printing)
Radar
Radio
Robot
Stereophonic sound system
Synthesizer
Tape recorder
Telephone
Telescope
Television
Typewriter
Video game
Videotape recorder
Watch (Electronic watches)
Wiretapping
Word processing

Other related articles

Atom
Communication (The development of electronics)
Electricity
Electron
Internet
Solid-state physics
Superconductivity
X rays (How X rays are produced)

Outline

I. Uses of electronics
A. In communications
B. Processing information
C. Medicine and research
D. Automation
II. How an electronic system works
III. Electronic circuits
A. How a circuit works
B. Types of electronic circuits
IV. Electron tubes
V. Solid-state components
A. Diodes
B. Transistors
VI. Passive components
VII. Electronics and light
A. Light-sensing devices
B. Light-emitting devices
C. Liquid crystal displays
VIII. How electronic circuits process information
A. Digital circuits
B. Analog circuits
C. Digital-analog conversion
IX. The electronics industry
A. Research and development
B. Manufacturing and sales
C. Careers in electronics
X. The development of electronics

Questions

How do electronics and the science of electricity differ in their use of electric current?
In what ways do conventional circuits differ from integrated circuits?
What advantages do semiconductor devices have over vacuum tubes?
What are the three main functions performed by transistors?
Why does electronic equipment that operates on a commercial power supply need a rectifier?
What is the difference between analog signals and digital signals?
What is a *p-n junction?* Why are p-n junctions important?
What are the three main elements that digital circuits need to process information?
What is a *microprocessor?*
How does a photodiode differ from an ordinary semiconductor diode?

Additional resources

Level I

Bonnet, Bob, and Keen, Dan. *Science Fair Projects with Electricity and Electronics.* Sterling Pub., 1996.

Bridgman, Roger F. *Electronics.* Dorling Kindersley, 1993.

Carrow, Robert S. *Put a Fan in Your Hat! Inventions, Contraptions, and Gadgets Kids Can Build.* Learning Triangle Pr., 1997.

Leon, George D. *Electronics Projects for Young Scientists.* Watts, 1991.

Level II

Brindley, Keith. *Starting Electronics.* Butterworth, 1994.

Cook, Nigel P. *Practical Electronics.* Prentice Hall, 1997.

Estabrooks, Maurice. *Electronic Technology, Corporate Strategy, and World Transformation.* Quorum Bks., 1995.

Frenzel, Louis E., Jr. *Crash Course in Electronics Technology.* 2nd ed. Newnes, 1996. Includes companion disk.

Graf, Rudolf F. *Modern Dictionary of Electronics.* 6th ed. Newnes, 1997.

Markus, John, and Sclater, N. J. *McGraw-Hill Electronics Dictionary.* 5th ed. McGraw, 1994.

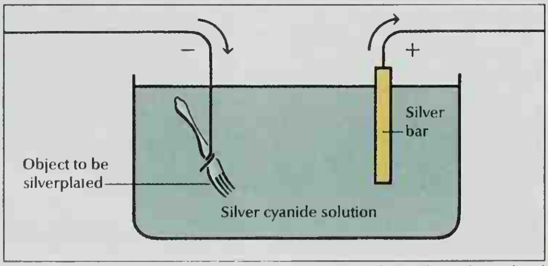
Electrophoresis, *ih LEHK troh fuh REE sihs,* is a method of separating and purifying large biological molecules, such as proteins and deoxyribonucleic acid (DNA), through the use of an electric field. Scientists use such purified molecules for chemical and medical purposes.

In electrophoresis, a solution containing a mixture of large molecules is placed on a *conductive support,* such as wet paper or a gel. An electric current is then applied to the solution, producing an electric field that causes the positively charged molecules to move in one direction and the negatively charged ones in another. In addition, the molecules of each substance in the solution have a specific charge and therefore move in the field at different rates. Eventually, the molecules are separated at different positions on the support. The current is then turned off, and the separated molecules are removed from the support. George McLendon

Electroplating, *ih LEHK truh PLAY tihng,* is the process of putting a metallic coating on a metal or other conducting surface by using an electric current. It is used to improve the appearance of materials, for protection against corrosion, and to make plates for printing.

The article to be plated is thoroughly cleaned of grease and dirt by dipping it in acid and alkaline cleaning solutions. It is then put in a solution of the metal with which it is to be coated. The metal exists in the form of *positive ions* (atoms that have lost one or more electrons). The article is connected to the *cathode* (negative end of a source of electric energy). The *anode* (positive electric terminal) is connected to another conductor which is also dipped into the solution. The electric current acts on the metallic ions in the solution. The ions are attracted to the cathode, and the coating is deposited on the article's metal surface. If the metal in the solution and the metal of the positive terminal are the same, the electric current may remove metal from the terminal to replace metal taken from the solution.

Electroplating



WORLD BOOK diagram by Sarah Woodward

Silverplating a fork involves applying an electric current to a silver cyanide solution. The current causes positively charged silver ions in the solution to be attracted to the fork.

The thickness of the layer deposited on the article depends on the strength of the electric current, the concentration of metallic ions, and the length of time the article has been in the solution. The terms *triple-plated* and *quadruple-plated* indicate various thicknesses of plating, not separate layers deposited on the surface.

Ornamental and protective platings are very thin, usually from $\frac{1}{1,000}$ to $\frac{2}{1,000}$ of an inch (0.03 to 0.05 millimeter) thick. For plating gold, silver, copper, zinc, and cadmium, cyanide solutions of the same metals are often used. Copper and zinc may also be plated by acid-sulfate solutions. Chromium is plated with a chromic-acid solution, and nickel is plated with nickel sulfate. Other metals plated for commercial use include platinum, lead, and tin. Alloys of two or more metals may be deposited by using a solution of salts of the metals that make up the alloy. Examples of alloys used for plating are brass, black nickel, lead-tin, and bronze.

Electroplating is also used to reproduce medals or other objects in a process called *electroforming.* This process was formerly known as *galvanoplasty.* One kind of electroforming, called *electrotyping,* is the reproduction of type forms and engravings for the printing industry. I. Melvin Bernstein

See also **Alloy; Electrolysis.**

Electroscope, *ih LEHK truh skohp,* is an instrument that detects the presence of an electric charge. Certain kinds of electroscopes, called *electrometers,* also measure the amount of charge present.

The simplest type of electroscope is the *gold-leaf electroscope.* This device has two slender strips of gold foil that hang straight down from a metal conductor. A nonconductor, such as cork, holds the conductor in a stand made of glass or metal. If an electrically charged object touches the conductor, the strips become charged. Both strips receive the same kind of charge and, because like charges repel each other, the strips spread apart in an upside-down V.

Gold-leaf and other simple electroscopes have been replaced by more sensitive *solid-state electrometers* for scientific research. These electronic instruments contain a *capacitor,* a device that stores an electric charge. When a charged object touches the electrometer's conductor, the charge produces a small voltage in the capacitor. The electrometer electronically amplifies this voltage so its value can be shown on a meter or on an instrument called an *oscilloscope* (see **Oscilloscope**).

Many people who work in areas where radiation may be present use an electroscope as a *dosimeter.* A dosimeter is a device that measures the amount of radiation to which a person has been exposed. An electroscope must be charged before it can be used as a dosimeter. It gradually discharges when exposed to gamma rays, X rays, or other forms of radiation. The amount of charge lost shows the level of exposure.

The first electroscope was made by William Gilbert, the physician of Queen Elizabeth I of England. He described it in a book published in 1600. Robert B. Prigo

See also Cosmic rays (Cosmic ray research).

Electroshock. See Shock treatment.

Electrostatic attraction. See Induction, Electric.

Electrotyping, *ih LEHK truh TY pihng,* is the process of making metal reproductions of type, engravings, or etchings for use in printing. This is done by *electroplating,* a process in which metal is deposited on a surface by electrical and chemical means. See also Electroplating; Photoengraving and photolithography; Printing.

Elegy. See Poetry (Lyric poetry); Gray, Thomas.

Element, Chemical, is any substance that contains only one kind of atom. All chemical substances are elements or *compounds* (combinations of elements). For example, hydrogen and oxygen are elements, and water is a compound of hydrogen and oxygen. Oxygen and silicon are the most plentiful elements in Earth's crust, accounting for about 47 percent and 28 percent of the crust's *mass* (amount of matter), respectively.

The International Union of Pure and Applied Chemistry (IUPAC) is the recognized authority in crediting the discovery of elements and assigning names to them. For a discovery to be recognized by IUPAC, scientists must produce a sample of the element and measure certain of its properties. In addition, IUPAC prefers that another experiment confirm the discovery. IUPAC recognizes the existence of 110 elements. Of those, 109 have official names. The remaining element is known as element 110. Scientists have also claimed the discovery of elements 111, 112, 114, and 116 (see Element 110; Element 111).

The *Periodic table of the elements* in this article lists the recognized elements in order of increasing *atomic number.* An atom's atomic number is the number of *protons* (positively charged particles) in its nucleus. All atoms of a given element have the same number of protons.

Names and symbols of elements

The names of some elements come from Greek or Latin words. *Bromine,* for example, comes from the Greek word for *stench* (foul odor). Many elements are named for a place or a person. Scientists at the University of California at Berkeley produced two new elements and named them berkelium and californium in honor of that city and state. Einsteinium was named for German-born American physicist Albert Einstein. Traditionally, the scientific community has granted an element's discoverer the right to name it, subject to acceptance by IUPAC.

Each named element has a chemical symbol consisting of one or two letters. In some cases, the symbol is the first letter of the name. For example, C is the symbol for carbon. If the first letter is already the symbol for another element, another letter of the name is used with the first. For instance, calcium has the symbol Ca. Some symbols come from an old name of the element. The symbol for lead, Pb, comes from *plumbum,* the Latin word for *lead.*

Chemists use symbols to write formulas for compounds. Formulas tell which elements and how many atoms of each are in a compound. See Compound.

Discovery of elements

Ancient people recognized the unique properties of a few substances that were later determined to be elements. Among the first of those were gold, copper, carbon, and sulfur. Small amounts of those elements occur naturally in pure, or nearly pure, form. As people discovered how to obtain pure metals from compounds, iron, lead, silver, tin, and other elements came to be known.

From the 1500's to the 1700's, experimenters discovered a few elements. The number of known elements began to increase rapidly in the mid-1700's. But even then, scientists had difficulty determining whether certain substances were elements or compounds. In the late 1700's, the French chemist Antoine Lavoisier created a system for classifying the known elements. But his list still included many compounds.

In 1869, two chemists, Dmitri Mendeleev of Russia and Julius Lothar Meyer of Germany, independently proposed an arrangement of the elements in what is now called the periodic table. Both scientists arranged the elements in order of increasing mass and according to similarity in properties, leaving gaps where no known element fit in. Based on the table, Mendeleev predicted the properties of three unknown elements, which were discovered between 1875 and 1886.

Ninety-three of the elements with atomic numbers 1 through 94 occur naturally on Earth. The exception is promethium—but astronomers have detected that element in a star. Scientists produced most of the 17 remaining recognized elements and elements 111, 112, 114, and 116 in machines called *particle accelerators.*

Researchers also first discovered neptunium, plutonium, and technetium as a result of accelerator experiments. Later, scientists found tiny amounts of those three elements that had been produced naturally on Earth. Elements are also created in nuclear reactors and the debris of nuclear explosions. See Particle accelerator.

The periodic table of the elements

The periodic table lists the elements in rows, called *periods,* in order of increasing atomic number. Elements with like properties lie in vertical columns called *groups.* The table also lists a mass for each element and the numbers of electrons in its *electron shells,* layers at various distances from the nucleus where the positively charged nucleus holds the negatively charged electrons according to how much energy they have. The table also indicates major *classes* of elements. For example, the *transition metals* class consists of metallic elements with an incomplete inner electron shell, such as gold and silver.

Some of the mass listings are *atomic mass numbers,* while others are *relative atomic masses.* To understand those listings and the electron shell listings, you need to know about the structure of atoms and a process known as *radioactive decay.* An atom consists of a tiny, positively charged nucleus surrounded by one or more negatively charged electrons. The nucleus of the simplest kind of hydrogen atom consists of a single proton. The nucleus of every other kind of atom has one or more protons and one or more electrically neutral particles called *neutrons.*

Most elements have more than one atomic form. The different forms have the same number of protons but different numbers of neutrons. Each form of an element is known as an *isotope* of that element.

Radioactive decay is a process in which one isotope turns into another. There are several forms of this process. In each, there is a change in the isotope's number of

Periodic table of the elements

This table gives information about the 110 recognized chemical elements. Eight major classes of elements are shown in different colors. Hydrogen is shown without color because it does not clearly belong to any one class. A key to the information about each element is at the right.

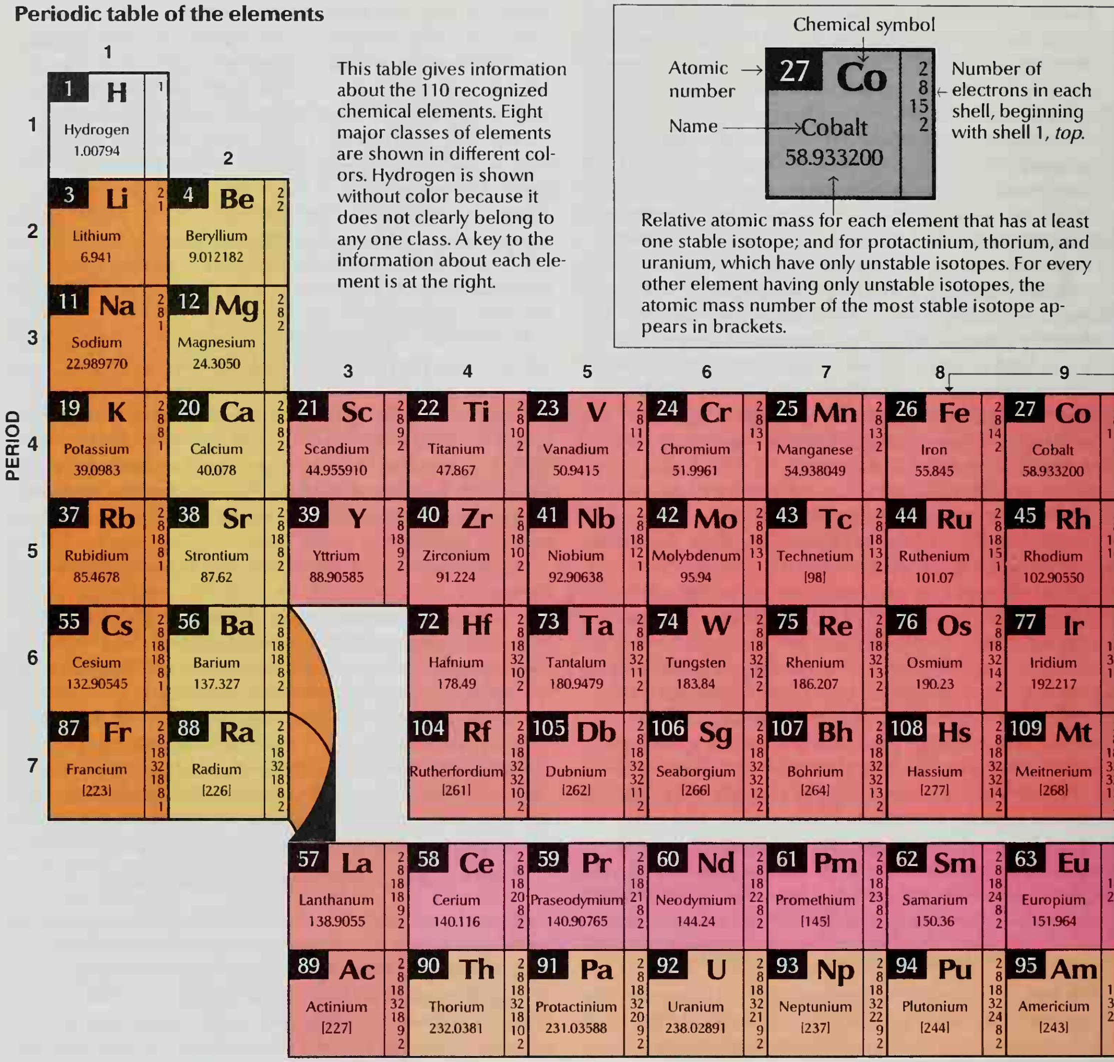


Table of the elements and their discoverers

Name	Symbol	Atomic number	Mass*	Discoverer	Country of discovery	Date of discovery
Actinium	Ac	89	[227]	André Debierne	France	1899
Aluminum	Al	13	26.981538	Hans Christian Oersted	Denmark	1825
Americium	Am	95	[243]	G. T. Seaborg; R. A. James; L. O. Morgan; A. Ghiorso	United States	1945
Antimony	Sb	51	121.760	Unknown; name applied to pure element in France in 1787		
Argon	Ar	18	39.948	Sir William Ramsay; Baron Rayleigh	United Kingdom	1894
Arsenic	As	33	74.92160	Uncertain; often credited to Albertus Magnus in Germany about 1250		
Astatine	At	85	[210]	D. R. Corson; K. R. MacKenzie; E. Segrè	United States	1940
Barium	Ba	56	137.327	Sir Humphry Davy	United Kingdom	1808
Berkelium	Bk	97	[247]	G. T. Seaborg; S. G. Thompson; A. Ghiorso	United States	1949
Beryllium	Be	4	9.012182	Friedrich Wöhler; A. A. Bussy	Germany; France	1828
Bismuth	Bi	83	208.98038	Unknown; preparation described in Germany in 1556		
Bohrium	Bh	107	[264]	Heavy Ion Research Center	Germany	1981
Boron	B	5	10.811	H. Davy; J. L. Gay-Lussac; L. J. Thenard	U.K.; France	1808
Bromine	Br	35	79.904	Antoine J. Balard; Carl J. Löwig	France; Germany	1826

*A number without brackets is a relative atomic mass. A number in brackets is the atomic mass number of the most stable isotope of an element having only unstable isotopes. Data are from the International Union of Pure and Applied Chemistry and other sources.

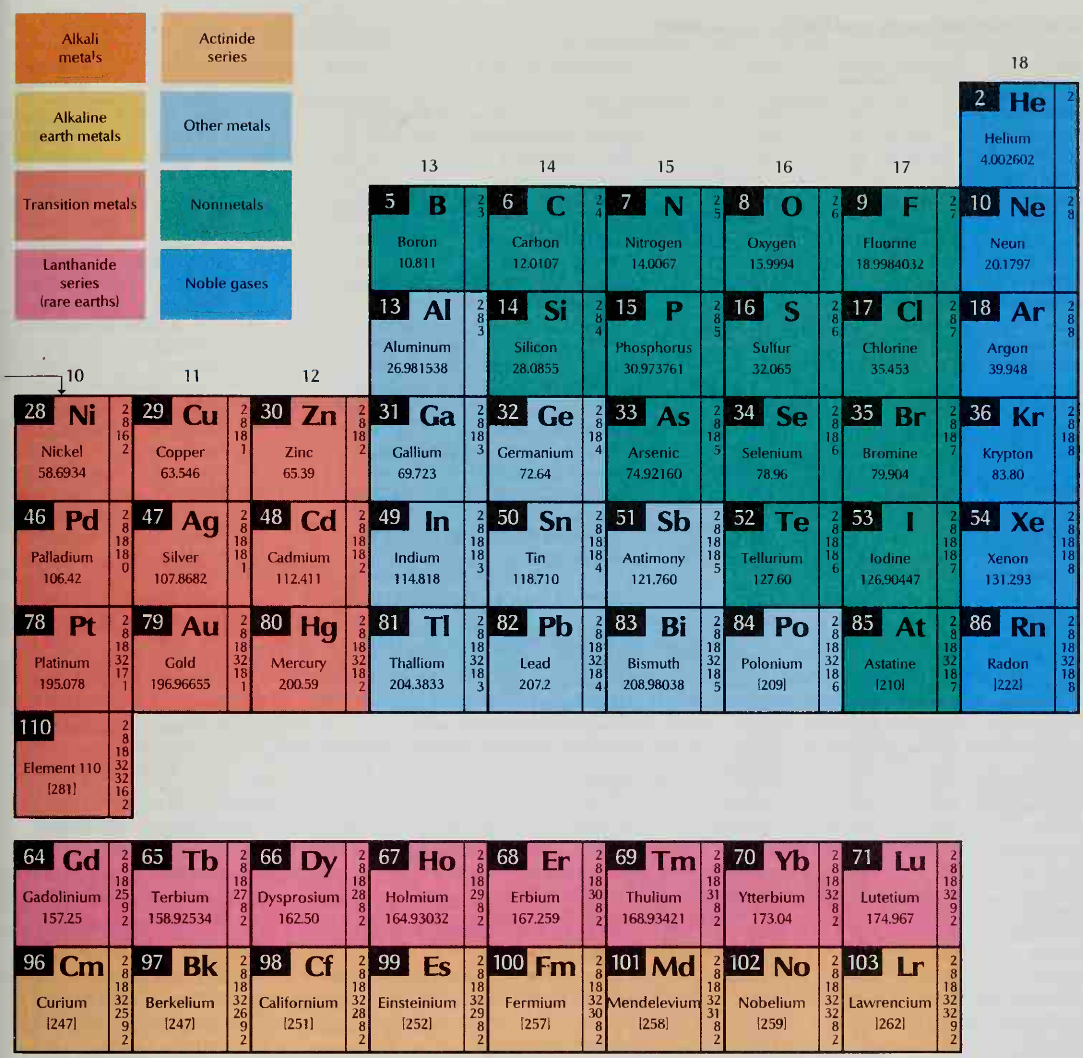


Table of the elements and their discoverers

Name	Symbol	Atomic number	Mass*	Discoverer	Country of discovery	Date of discovery
Cadmium	Cd	48	112.411	Friedrich Stromeyer	Germany	1817
Calcium	Ca	20	40.078	Sir Humphry Davy	Britain	1808
Californium	Cf	98	[251]	G. T. Seaborg; S. G. Thompson; A. Ghiorso; K. Street, Jr.	United States	1950
Carbon	C	6	12.0107		Known to ancients	
Cerium	Ce	58	140.116	W. von Hisinger; J. Berzelius; M. Klaproth	Sweden; Germany	1803
Cesium	Cs	55	132.90545	Gustav Kirchhoff; Robert Bunsen	Germany	1860
Chlorine	Cl	17	35.453	Carl Wilhelm Scheele	Sweden	1774
Chromium	Cr	24	51.9961	Louis Vauquelin	France	1797
Cobalt	Co	27	58.933200	Georg Brandt	Sweden	Late 1730's
Copper	Cu	29	63.546		Known to ancients	
Curium	Cm	96	[247]	G. T. Seaborg; R. A. James; A. Ghiorso	United States	1944
Dubnium	Db	105	[262]	Joint Institute for Nuclear Research	Russia†	1971
				Lawrence Berkeley National Laboratory ‡	United States	1970
Dysprosium	Dy	66	162.50	Paul Émile Lecoq de Boisbaudran	France	1886

*A number without brackets is a relative atomic mass. A number in brackets is the atomic mass number of the most stable isotope of an element having only unstable isotopes.
†Then part of the Soviet Union.
‡Then Lawrence Radiation Laboratory

Table of the elements and their discoverers

Name	Symbol	Atomic number	Mass*	Discoverer	Country of discovery	Date of discovery
Einsteinium	Es	99	[252]	Argonne; Los Alamos; Berkeley	United States	1952
Element 110		110	[281]	Heavy Ion Research Center	Germany	1994
Erbium	Er	68	167.259	Carl Mosander	Sweden	1843
Europium	Eu	63	151.964	Eugène Demarçay	France	1901
Fermium	Fm	100	[257]	Argonne; Los Alamos; U. of Calif.	United States	1953
Fluorine	F	9	18.9984032	Henri Moissan	France	1886
Francium	Fr	87	[223]	Marguerite Perey	France	1939
Gadolinium	Gd	64	157.25	Jean de Marignac	Switzerland	1880
Gallium	Ga	31	69.723	Paul Émile Lecoq de Boisbaudran	France	1875
Germanium	Ge	32	72.64	Clemens Winkler	Germany	1886
Gold	Au	79	196.96655		Known to ancients	
Hafnium	Hf	72	178.49	Dirk Coster; Georg von Hevesy	Denmark	1923
Hassium	Hs	108	[277]	Heavy Ion Research Center	Germany	1984
Helium	He	2	4.002602	Sir William Ramsay; Nils Langlet; P. T. Cleve	Britain; Sweden	1895
Holmium	Ho	67	164.93032	J. L. Soret	Switzerland	1878
Hydrogen	H	1	1.00794	Henry Cavendish	Britain	1766
Indium	In	49	114.818	Ferdinand Reich; H. Richter	Germany	1863
Iodine	I	53	126.90447	Bernard Courtois	France	1811
Iridium	Ir	77	192.217	Smithson Tennant	Britain	1804
Iron	Fe	26	55.845		Known to ancients	
Krypton	Kr	36	83.80	Sir William Ramsay; M. W. Travers	Britain	1898
Lanthanum	La	57	138.9055	Carl Mosander	Sweden	1839
Lawrencium	Lr	103	[262]	Joint Institute for Nuclear Research Lawrence Berkeley National Laboratory‡	Russia† United States	1961- 1971
Lead	Pb	82	207.2		Known to ancients	
Lithium	Li	3	6.941	Johann Arfvedson	Sweden	1817
Lutetium	Lu	71	174.967	Georges Urbain	France	1907
Magnesium	Mg	12	24.3050	Sir Humphry Davy	Britain	1808
Manganese	Mn	25	54.938049	Johan Gahn	Sweden	1774
Meitnerium	Mt	109	[268]	Heavy Ion Research Center	Germany	1982
Mendelevium	Md	101	[258]	Lawrence Berkeley National Laboratory‡	United States	1958
Mercury	Hg	80	200.59		Known to ancients	
Molybdenum	Mo	42	95.94	Carl Wilhelm Scheele	Sweden	1778
Neodymium	Nd	60	144.24	C. F. Auer von Welsbach	Austria	1885
Neon	Ne	10	20.1797	Sir William Ramsay; M. W. Travers	Britain	1898
Neptunium	Np	93	[237]	E. M. McMillan; P. H. Abelson	United States	1940
Nickel	Ni	28	58.6934	Axel Cronstedt	Sweden	1751
Niobium	Nb	41	92.90638	Charles Hatchett	Britain	1801
Nitrogen	N	7	14.0067	Daniel Rutherford	Britain	1772
Nobelium	No	102	[259]	Joint Institute for Nuclear Research	Russia†	1966
Osmium	Os	76	190.23	Smithson Tennant	Britain	1804
Oxygen	O	8	15.9994	Joseph Priestley; Carl Wilhelm Scheele	Britain; Sweden	1774
Palladium	Pd	46	106.42	William Wollaston	Britain	1803
Phosphorus	P	15	30.973761	Hennig Brand	Germany	1669
Platinum	Pt	78	195.078	Julius Scaliger	Italy	1557
Plutonium	Pu	94	[244]	G. T. Seaborg; J. W. Kennedy; E. M. McMillan; A. C. Wahl	United States	1940
Polonium	Po	84	[209]	Pierre and Marie Curie	France	1898
Potassium	K	19	39.0983	Sir Humphry Davy	Britain	1807
Praseodymium	Pr	59	140.90765	C. F. Auer von Welsbach	Austria	1885
Promethium	Pm	61	[145]	J. A. Marinsky; Lawrence E. Glendenin; Charles D. Coryell	United States	1945
Protactinium	Pa	91	231.03588	Otto Hahn; Lise Meitner; Frederick Soddy; John Cranston	Germany; Britain	1917
Radium	Ra	88	[226]	Pierre and Marie Curie	France	1898
Radon	Rn	86	[222]	Friedrich Ernst Dorn	Germany	1900
Rhenium	Re	75	186.207	Walter Noddack; Ida Tacke; Otto Berg	Germany	1925
Rhodium	Rh	45	102.90550	William Wollaston	Britain	1803
Rubidium	Rb	37	85.4678	R. Bunsen; G. Kirchhoff	Germany	1861
Ruthenium	Ru	44	101.07	Karl Klaus	Russia	1844
Rutherfordium	Rf	104	[261]	Joint Institute for Nuclear Research Lawrence Berkeley National Laboratory‡	Russia† United States	1969- 1970
Samarium	Sm	62	150.36	Paul Émile Lecoq de Boisbaudran	France	1879
Scandium	Sc	21	44.955910	Lars Nilson	Sweden	1879
Seaborgium	Sg	106	[266]	Lawrence Berkeley National Laboratory§ Lawrence Livermore National Laboratory#	United States	1974
Selenium	Se	34	78.96	Jöns Berzelius	Sweden	1817
Silicon	Si	14	28.0855	Jöns Berzelius	Sweden	1823

*A number without brackets is a relative atomic mass. A number in brackets is the atomic mass number of the most stable isotope of an element having only unstable isotopes.

†Then part of the Soviet Union

‡Then Lawrence Radiation Laboratory

§Then Lawrence Berkeley Laboratory.

#Then Lawrence Livermore Laboratory.

Table of the elements and their discoverers

Name	Symbol	Atomic number	Mass*	Discoverer	Country of discovery	Date of discovery
Silver	Ag	47	107.8682		Known to ancients	
Sodium	Na	11	22.989770	Sir Humphry Davy	Britain	1807
Strontium	Sr	38	87.62	A. Crawford	Britain	1790
Sulfur	S	16	32.065		Known to ancients	
Tantalum	Ta	73	180.9479	Anders Ekeberg	Sweden	1802
Technetium	Tc	43	[98]	Carlo Perrier; Émilio Segrè	Italy	1937
Tellurium	Te	52	127.60	Franz Müller von Reichenstein	Romania	1782
Terbium	Tb	65	158.92534	Carl Mosander	Sweden	1843
Thallium	Tl	81	204.3833	Sir William Crookes	Britain	1861
Thorium	Th	90	232.0381	Jöns Berzelius	Sweden	1828
Thulium	Tm	69	168.93421	Per Theodor Cleve	Sweden	1879
Tin	Sn	50	118.710		Known to ancients	
Titanium	Ti	22	47.867	William Gregor	Britain	1791
Tungsten	W	74	183.84	Fausto and Juan José de Elhuyar	Spain	1783
Uranium	U	92	238.02891	Martin Klaproth	Germany	1789
Vanadium	V	23	50.9415	Nils Sefström	Sweden	1830
Xenon	Xe	54	131.293	Sir William Ramsay; M. W. Travers	Britain	1898
Ytterbium	Yb	70	173.04	Jean de Marignac	Switzerland	1878
Yttrium	Y	39	88.90585	Johann Gadolin	Finland	1794
Zinc	Zn	30	65.39	Andreas Marggraf	Germany	1746
Zirconium	Zr	40	91.224	Martin Klaproth	Germany	1789

*A number without brackets is a relative atomic mass. A number in brackets is the atomic mass number of the most stable isotope of an element having only unstable isotopes.

protons, number of neutrons, or both. Because the number of protons distinguishes one element from another, any change in the number of protons produces a different element. Such a change is called a *transmutation.*

An isotope that might decay is considered to be *unstable.* A *stable* isotope cannot decay. Of the 110 recognized elements, 81 have one or more stable isotopes. The remaining 29 have only unstable isotopes.

Different isotopes decay at different rates. The rate at which a given isotope decays is that isotope's *half-life*—the time taken for half the atoms in a sample of that isotope to decay. Half-lives vary tremendously. The half-life of meitnerium 268 is less than $\frac{1}{10}$ of a second; the half-life of uranium 238 is almost 4 $\frac{1}{2}$ billion years.

To determine the half-life of an isotope, scientists measure the decay times of many atoms of that isotope. But when scientists have used particle accelerators to create isotopes of the heaviest elements in the periodic table—heavier than element 106, seaborgium—they have often produced only a few atoms of those isotopes. Those atoms and their decays have been detected one at a time. As a result, scientists do not express the stability of such isotopes in terms of half-life. Instead, they state the time between the creation of the isotope and its decay. They may give the value for a single atom or a range—or an average value—for all the atoms.

Atomic mass number. An isotope's atomic mass number is the total number of protons and neutrons in its nucleus. Chemists commonly designate an isotope by the name of the element followed by the isotope's atomic mass number. Thus, *copper 63* is an isotope of copper whose atomic mass number is 63. An atom of that isotope has 29 protons and 34 neutrons in its nucleus.

Relative atomic mass is the ratio of the mass of an isotope or an element to $\frac{1}{12}$ of the mass of an atom of carbon 12, the most abundant form of carbon. Thus, carbon 12 serves as a mass standard for all other isotopes. An older term for relative atomic mass is *atomic weight.*

For an element with only one stable isotope, the relative atomic mass equals the mass of that isotope divided by $\frac{1}{12}$ of the mass of carbon 12. For an element with two or more stable isotopes, the relative atomic mass is an average value. That value depends on two factors: (1) the masses of the stable isotopes and (2) and the proportions in which those isotopes occur in nature.

For example, copper 63 and copper 65 are the only stable isotopes of that metal. Of the copper in nature, 69.17 percent is copper 63, which has a relative atomic mass of 62.93. The remaining 30.83 percent is copper 65, with a relative atomic mass of 64.93. The calculation for the relative atomic mass of copper is: $(62.93 \times 0.6917) + (64.93 \times 0.3083) = 63.55$. In this sample calculation, the values are rounded to four digits, and so the answer is approximate. The precise value listed in the table is 63.546.

The periodic table lists the relative atomic mass of each of the 81 elements that have at least one stable isotope. Of the 29 elements with only unstable isotopes, thorium, protactinium, and uranium are most like elements with stable isotopes. Those three elements are plentiful in nature and have isotopes with long half-lives. As a result, the table also lists the average relative atomic masses of the three. The table lists atomic mass numbers for the remaining 26 elements that have only unstable isotopes. In each case, the number listed is the atomic mass number of the isotope with the longest half-life.

Groups. Each column in the table lists a group of elements with similar chemical behavior—that is, they behave somewhat alike in forming compounds. Each group has a number from 1 to 18. The groups include the elements created only in particle accelerators. But scientists have not formed compounds with all those elements, so their chemical behavior is not always well known.

Electron shells. The similar behavior of elements in a group results from a similarity in their atoms' structure. An electrically balanced atom has the same number of electrons as there are protons in the atomic nucleus. The electrons are arranged in levels called electron shells, according to how much energy the electrons have. Generally, those closest to the nucleus have the least energy. When an electron absorbs energy, it either moves to a

higher-energy shell or leaves the atom. Electrons in outer shells need to absorb the least energy to leave the atom.

Chemical reactions involve electrons' movement between atoms or a sharing of electrons by atoms. Thus, the electrons in an atom's outer shells control the atom's chemical behavior. In most groups in the table, the elements' outer shells have the same number of electrons.

Each electron shell has a number. The shell closest to the nucleus is *shell 1.* Each shell can hold only a certain quantity of electrons. Shells 1, 2, 3, 4, 5, 6, and 7 can hold, respectively, a maximum of 2, 8, 18, 32, 50, 72, and 98 electrons. However, no element has even five full shells because electrons tend to move to outer shells before the inner shells are full. The seven shells are sometimes called the K, L, M, N, O, P, and Q shells.

Classes. The periodic table uses colors to indicate classes of elements that have similar properties. For example, the table in this article uses dark blue for the *noble gases,* gases that do not combine readily with other elements. For information about classes of elements, see **Alkali; Metal; Noble gas; Rare earth.** Richard L. Hahn

Related articles. Each officially recognized element has a separate article in *World Book.*

Additional resources

Knapp, Brian J. *Elements.* 18 vols. Rev. ed. Grolier, 2002. Younger readers.
Stwertka, Albert. *A Guide to the Elements.* 2nd ed. Oxford, 2002.

Element 110 is an artificially produced radioactive element. It has an *atomic number* (number of protons) of 110. Scientists have reported six *isotopes* of element 110, forms of the element with the same number of protons but different numbers of neutrons. The *atomic mass numbers* (total numbers of protons and neutrons) of those isotopes range from 267 to 281.

In 1994, an international group of scientists working at the Heavy Ion Research Center in Darmstadt, Germany, became the first to produce element 110. They used a machine called a *particle accelerator* to bombard lead, which has an atomic number of 82, with nickel, whose atomic number is 28. The first atom of element 110 produced was an atom of *isotope 269*—that is, the atom had an atomic mass number of 269. That atom *decayed* (broke apart in a radioactive process) in 0.00017 second.

The atom of element 110 with the longest lifetime was an atom of isotope 281. That atom decayed in 1.6 minutes.

In 2000, the International Union of Pure and Applied Chemistry (IUPAC) credited the discovery of Element 110 to the Darmstadt group. IUPAC is the recognized authority in crediting the discovery of elements and assigning names to them By mid-2002, IUPAC had not yet assigned a name to element 110. Richard L. Hahn

Element 111 is an artificially produced radioactive element. It has an *atomic number* (number of protons) of 111. Scientists have reported only one *isotope* of element 111. An isotope is any of two or more forms of an element that have the same number of protons but different numbers of neutrons. The one known isotope of element 111 has an *atomic mass number* (total number of protons and neutrons) of 272. Its *half-life* is 0.0015 second—that is, due to radioactive decay, only half the atoms in a sample of isotope 272 would still be atoms of that isotope after 0.0015 second.

In December 1994, an international group of scientists at the Heavy Ion Research Center in Darmstadt, Germany, became the first to claim the production of element 111. They bombarded bismuth, whose atomic number is 83, with nickel, whose atomic number is 28. The process produced three atoms of element 111.

By mid-2002, the International Union of Pure and Applied Chemistry (IUPAC) had not credited the discovery of element 111, nor had it proposed a name for the element. That organization is the recognized authority in crediting the discovery of elements and assigning names to them. Richard L. Hahn

Elementary and Secondary Education Act (ESEA) was the first major program of the United States government that was designed specifically to improve elementary and secondary education. The United States Congress passed the act in 1965 to support the federal government's aim of ending poverty in the nation. Under the 1964 Civil Rights Act, ESEA funds could go only to schools complying with federal desegregation orders. The U.S. Office of Education (now the Department of Education) administered ESEA.

Title I of the act established programs to help lower-income children designated as "educationally deprived." The programs included remedial reading and mathematics programs and special summer programs. Other sections of the act included benefits not limited to lower-income students.

A 1966 amendment to ESEA provided funds for educational programs and facilities for children with disabilities. A 1968 amendment supplied funds for bilingual education programs.

The Educational Consolidation and Improvement Act of 1981 was designed to update and improve ESEA services. It gave states more power to decide how to spend ESEA funds and reduced the need of the federal government to administer so many separate programs. Since 1981, Congress has reauthorized many ESEA programs.

In 2001, Congress passed legislation reauthorizing and revising ESEA and redefining the federal government's role in public education. The law, called the No Child Left Behind Act, increased federal aid for public schools and introduced new federal requirements for student testing. It aimed to hold schools accountable for student progress and to assist students in schools that performed poorly. Frances Schoonmaker Bolin

Elementary school is a school for children from age 5 or 6 to age 12 or 14. Most elementary schools have six grades, though some have eight. Many of the schools include a kindergarten. Some elementary schools end with grade four, five, or six, and the students then enter a two-, three-, or four-year *middle school* or *junior high school.* Others, called *primary schools,* cover only the first three grades. Elementary schools are sometimes called *grade schools* or *grammar schools.*

This article discusses types of elementary schools and how students are taught. For information on the history of elementary schools and for the number of elementary schools in the United States and Canada, see **School.** For enrollments in elementary schools in the United States and Canada, see **Education** (table; Students, teachers, and school expenditures).

Kinds of elementary schools. United States elementary schools may be *public, private,* or *parochial.* Public

Building language skills is a major goal of elementary instruction. These students are using books, computers, and audio recordings as tools in reading, writing, and listening projects.

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schools are free and are supported by taxes. Private schools charge tuition and receive additional support from donations and gifts. Parochial schools are private schools operated by religious groups.

Most elementary schools are organized as *graded* schools, where pupils of the same age study together. But some communities have *nongraded* or *ungraded* schools. Students in these schools are grouped according to ability and interest, and they advance in each subject at their own rate.

Elementary school instruction emphasizes three major areas of study: (1) communication, including reading, writing, listening, and speaking; (2) computation, which involves understanding and using numbers; and (3) character development, which deals with children's relationships with one another and their surroundings. In addition, teachers instruct students in such subjects as art, computers, health, music, science, and social studies.

Elementary schools seek to help children expand their knowledge of the world around them. The curriculum in many schools is based on a theme of expanding environments. In the first grade, pupils learn about the home and the family. Second-graders study the school and the neighborhood. In the third grade, teachers introduce information about one's own community in comparison with others. The fourth-grade program deals with the state. Fifth-graders study the nation, and sixth-graders the world. In all grades, teachers help children develop social skills and help them learn to get along as members of a group.

Most elementary schools are divided into rooms in which one teacher instructs about 25 children. Such rooms are called *self-contained classrooms.* But some elementary schools have *open space classrooms,* sometimes called open classrooms. These classrooms have no walls separating them, or they have movable walls. Several classes may work together in one large area, or small groups may work separately. Both types of classrooms may have learning centers, where many kinds of instructional materials are available for students.

In lower or primary elementary grades, students may spend all or most of the day with one teacher. In the upper or intermediate grades, pupils may have special teachers for such subjects as art, music, physical education, and science. Some elementary schools use *team teaching,* in which a team of several teachers and teacher aides is responsible for 100 or more pupils.

Stephen M. Fain

See also **Alternative school; Early childhood education; Education** (Elementary education); **Parochial school; Private school.**

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Outdoor play at lunch or recess gives elementary school students fresh air, exercise, and a break from classroom activities. Play also provides an opportunity to see friends and develop social skills.

Cynthia Moss

Elephants live in families of related females and their young. A family is led by the oldest female, called the *matriarch.* The family shown here is grazing in a grassy clearing in Kenya. The matriarch is in the center front. The largest animal on the left is a visiting male.

Elephant is the largest animal that lives on land. Among all animals, only some kinds of whales are larger. The elephant is also the second tallest member of the animal kingdom. Only the giraffe is taller. Elephants are the only animals that have a nose in the form of a long trunk, which they use as a hand. They have larger ears than any other animal, and their tusks are the largest teeth.

There are two chief kinds of elephants, *African elephants* and *Indian elephants,* also known as *Asian elephants.* African elephants live only in Africa south of the Sahara. Indian elephants live in parts of India and Southeast Asia.

Elephants are extremely strong and highly intelligent. People have tamed and trained them for thousands of years. The logging industry in some Asian countries uses elephants to carry heavy loads. People throughout the world enjoy watching elephants in circuses and zoos. Trained circus elephants stand on their heads, lie down and roll over, dance, and perform other tricks.

One of the earliest recorded uses of elephants took place in war. In 331 B.C., a Macedonian army led by Alexander the Great defeated Persian soldiers who rode elephants in battle. In 218 B.C., the famous general Hannibal of Carthage used elephants when he crossed the Alps and invaded Italy.

During the 1800's, an African elephant named Jumbo was featured by the London Zoo for more than 17 years. Visitors came from all parts of the world to see Jumbo, the largest animal in captivity at that time. He stood 11 feet (3.4 meters) tall and weighed more than 14,500 pounds (6,600 kilograms). In 1882, the American showman P. T. Barnum purchased Jumbo and made the elephant a star attraction of his circus. The word *jumbo* became a common adjective for anything extremely large.

Some people travel to Africa and parts of Asia to see wild elephants in their own environment. However, the number of wild elephants has been steadily declining because people kill elephants for their ivory tusks. In addition, people have settled on much of the land where the animals lived, resulting in a loss of habitat for the elephants. Farming and industry threaten the natural resources needed by elephants to survive. In Asia, human population growth has reduced the number of elephants to between 35,000 and 51,000. In Africa, the main cause of the decline in elephants is illegal hunting. In 1979, an estimated 1,300,000 elephants lived in Africa. In the early 1990's, there were only about 600,000.

A public awareness campaign was launched in the late 1980's to save the African elephant. People throughout the world were made aware that thousands of elephants were being slaughtered every year to provide ivory jewelry and carvings. Japan was the greatest consumer of ivory. The Japanese used half the ivory that they imported for signature seals, traditional carved stamps used to print their names in ink. It was estimated that 12,000 elephants were killed each year to obtain ivory for these seals.

The importance of elephants

Wild elephants perform several important natural functions. For example, they help turn densely wooded areas into more open areas by feeding on trees and

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other plants. More kinds of animals can live in these open habitats. Elephants also dig up dry riverbeds to reach the water beneath the surface of the ground. Other animals then drink this water. When elephants travel through wooded areas, they create paths used by such animals as antelope and zebras.

Kinds of elephants

African elephants are larger than Indian elephants. Wild African elephants live only in Africa south of the Sahara.

An African elephant is about the same height at the shoulder and the rump. Its back dips slightly in the middle. Adult African *bull* (male) elephants stand about 11 feet (3.4 meters) tall at the shoulder and weigh about 12,000 pounds (5,400 kilograms). The *cows* (females) are about 9 feet (2.8 meters) tall and weigh about 8,000 pounds (3,600 kilograms). The largest known elephant, an African bull, measured 13 feet 2 inches (4.01 meters) tall. The heaviest elephant ever weighed was over 14,500 pounds (6,600 kilograms).

Most African elephants have dark gray skin. Their forehead forms a smooth curve. Their ears measure as wide as 4 feet (1.2 meters) and cover their shoulders. Both the bulls and cows have tusks. The tusks of most African bulls grow from 6 to 8 feet (1.8 to 2.4 meters) long and weigh 50 to 100 pounds (23 to 45 kilograms) each. The tusks of most of the cows weigh from 15 to 20 pounds (7 to 9 kilograms) each. The longest tusk of an African elephant measured 11 ½ feet (3.5 meters), and the heaviest weighed 293 pounds (133 kilograms).

The trunk of an African elephant has two fleshy, fingerlike structures on the tip. The skin of the trunk has deep wrinkles. African elephants have four or five toes on each forefoot and three toes on each hind foot. A loose fold of skin joins the hind legs and the sides of the body. Indian elephants do not have this fold.

There are two types of African elephants, *bush elephants* and *forest elephants.* Bush elephants, which live in most countries south of the Sahara, are the larger and have heavier tusks. Forest elephants live in Cameroon, Congo (Brazzaville), Congo (Kinshasa), Ivory Coast, and other countries of central and western Africa. Both kinds of African elephants inhabit forests, grasslands, mountains, swamps, and shrubby areas.

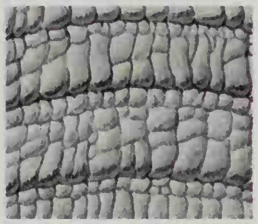
Indian elephants live only in southern and southeastern Asia. They are found in forests and jungles of Cambodia, China, India, Indonesia, Malaysia, Myanmar, Sri Lanka, Thailand, and Vietnam.

Indian elephants have an arched back that is slightly higher than the shoulder and the rump. An adult Indian bull stands from 9 to 10 ½ feet (2.7 to 3.2 meters) tall at the shoulder and weighs up to 8,000 pounds (3,600 kilograms). The largest known Indian bull measured 10 feet 8 inches (3.3 meters) tall. Indian cows stand about 8 feet (2.4 meters) tall and weigh about 6,600 pounds (3,000 kilograms).

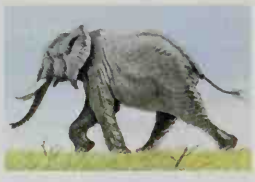
Most Indian elephants have light gray skin and may have pink or white spots. An Indian elephant has two humps on its forehead just above the ears. The ears are about half as large as those of an African elephant and do not cover the shoulder. Most Indian bulls have tusks that grow from 4 to 5 feet (1.2 to 1.5 meters) long. However, some Indian males, called *makhnas,* have no

Interesting facts about elephants

The skin of an elephant is gray and wrinkled. An adult elephant's skin measures up to 1 ½ inches (3 centimeters) thick and weighs about 1 ton (0.9 metric ton). However, it is surprisingly tender. Flies, mosquitoes, and other insects can bite into the skin.



An angry or frightened elephant can run at a speed of more than 25 miles (40 kilometers) an hour for a short distance. On a long journey, a herd of elephants travels at about 10 miles (16 kilometers) an hour.



An elephant uses its trunk as a hand. The trunk can carry a 600-pound (272-kilogram) log or an object as small as a coin. Elephants also breathe and smell with their trunks.

Elephants love water and frequently bathe in lakes and rivers. They are excellent swimmers. An elephant gives itself a shower by shooting a stream of water from its trunk.

WORLD BOOK illustrations by James Teason

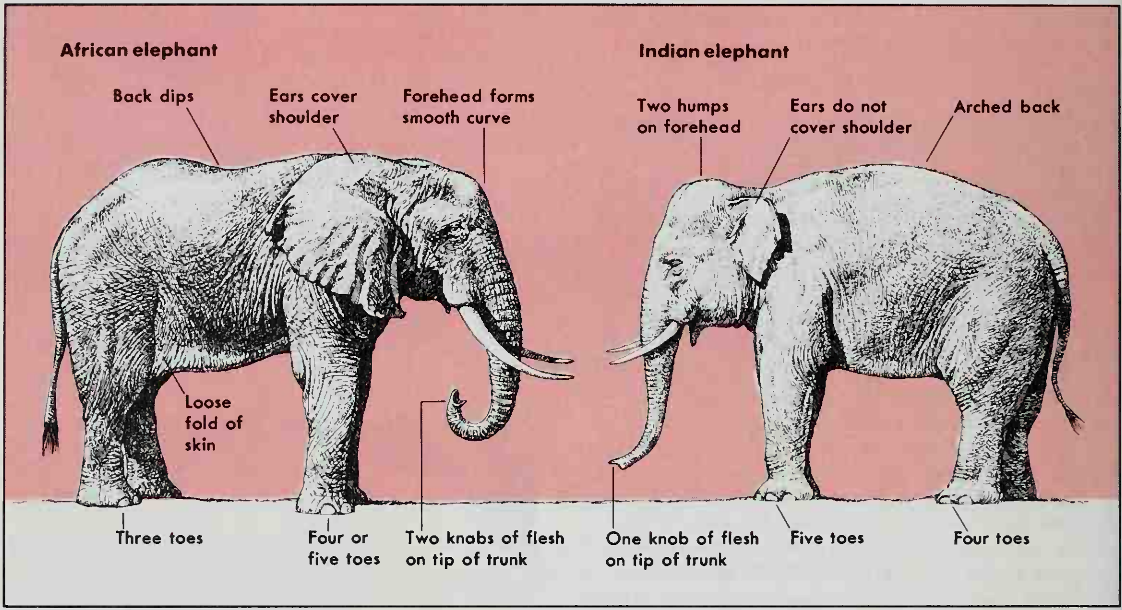
Neal Ulevich

Trained elephants, such as the Asiatic elephant shown here, are used in the logging industry in several Asian countries. An elephant can carry heavy loads with its trunk or on its back.

How African and Indian elephants differ

The two chief kinds of elephants, African elephants and Indian elephants, differ in size and body features. For example, African elephants are larger and have bigger tusks. These drawings show various physical differences between the two species.

WORLD BOOK illustrations by John D. Dawson



tusks, and most Indian females have none. Most Indian females have extremely short tusks called *tushes.*

The trunk of an Indian elephant has smoother skin than that of an African elephant and only one fingerlike structure on the tip. Most Indian elephants have five toes on each forefoot and four on each hind foot.

The body of an elephant

The height of an adult elephant about equals the length of the back of the elephant from head to tail. Scientists may or may not include the length of the trunk as well when giving the total length. An elephant has a short, muscular neck and an enormous head with huge, triangular ears. The trunk extends from the upper jaw, and a tusk may grow from each side of the jaw at the base of the trunk. Massive legs support the body. An elephant's tail is small in relation to the rest of the animal. It measures about $3\frac{1}{3}$ feet (1 meter) long.

Skin and hair. Elephants have gray, wrinkled skin that hangs in loose folds. The skin of an adult measures up to $1\frac{1}{2}$ inches (3 centimeters) thick. It weighs about 2,000 pounds (900 kilograms). Elephants are called *pachyderms,* a term that comes from a Greek word meaning *thick-skinned.* However, an elephant's skin is surprisingly tender. Some insects, including flies and mosquitoes, can bite into the skin.

An elephant has no sweat glands, and so it must cool off in other ways. It may get rid of excess body heat by flapping its enormous ears or by spraying water on itself. Elephants also stay cool by rolling in mud. The mud dries on the skin and thus shields it from the sun.

At birth, elephants are often covered with sparse brown, black, or reddish-brown hair that gradually wears off as they get older. Adult elephants appear to be nearly hairless. But there are bristles around the ears, eyes, and mouth, and sparse hair on the trunk, legs, and other parts of the body. The end of the tail has a long bunch of thick hairs.

Trunk. An elephant's trunk is a combined nose and upper lip. It consists of a strong, flexible, boneless mass of flesh. The trunk of an adult elephant measures about 5 feet (1.5 meters) long and weighs about 300 pounds (140 kilograms).

An elephant breathes and smells with its trunk and uses it when eating and drinking. The animal sniffs the air and the ground almost constantly with its trunk. It carries food and water to its mouth with its trunk. It also gives itself a shower by sucking water into the trunk and then spraying it out again. The trunk of an adult can hold about $1\frac{1}{2}$ gallons (6 liters) of water.

An elephant grasps objects with its trunk much as a person does with a hand. The trunk can carry a log that weighs as much as 600 pounds (272 kilograms). The tip of the trunk can pick up an object as small as a coin. An elephant also uses its trunk to communicate with other elephants. When two elephants greet each other, each places the tip of its trunk in the other's mouth. A mother will comfort her calf by stroking it with her trunk. Young males play-fight by wrestling with their trunks. In a true fight, the trunk is usually protected by curling it under the chin.

Tusks and teeth. An elephant's tusks are actually long, curved upper teeth called *incisors.* They are made of ivory. About two-thirds of each tusk extends from the upper jaw. The rest is in the skull. Elephants use their tusks to dig for food and water and to fight. The tusks can lift and carry a load weighing as much as 2,000 pounds (900 kilograms). Most Indian females and some Indian males have no tusks.

Elephants also have four *molars* (back teeth). The mo-

lars of an adult may measure 1 foot (30 centimeters) long and weigh about $8\frac{1}{2}$ pounds (4 kilograms). These teeth have jagged edges that help grind food. One molar lies on each side of both jaws, and additional molars form in the back of the mouth. The molars in front gradually wear down and drop out, and the ones in back push forward and replace them. An elephant grows six sets of molars during its lifetime. Each set consists of four teeth. The last set of molars appears when the animal is about 40 years old.

Legs and feet. The legs of an elephant are pillarlike structures. The feet are nearly round. Each foot has a thick pad of tissue that acts as a cushion. The foot expands under the elephant's weight and contracts when the animal lifts the leg. Elephants may sink deep into mud, but they can pull their legs out easily because the feet become smaller when lifted.

Senses. The trunk provides a keen sense of smell, and elephants depend on this sense more than on any other. They frequently wave their trunks high in the air to catch the scent of food or enemies. An elephant can smell a human being more than a mile (1.6 kilometers) away.

Elephants also have good hearing. They can make and hear sounds below the range of human hearing. These low sounds, called *infrasound,* travel farther than higher sounds. Elephants can communicate with each other at a distance of at least $2\frac{1}{2}$ miles (4 kilometers), and possibly twice that distance.

The elephant's sense of touch is most keen in its trunk, especially at the tip. An elephant can recognize the shape of an object and whether the object is rough or smooth and hot or cold.

Elephants have poor sight. Their eyes are small in relation to the enormous head. An elephant cannot turn its head completely, and so it can see only in the front and to the sides. The animal must turn around to see anything behind it.

Intelligence. Elephants have a large brain and rank high in intelligence among animals. In the wild, their social lives are complex and involve learning many behaviors and communication skills. Studies of the African elephant have shown that these animals make at least 25 different calls, each with a specific meaning. Elephants have excellent memories, which they use both in their social activities and in their travels over large areas. It seems that the *matriarch* (ruling mother) is the carrier of knowledge for the whole family. She knows the migration routes, where to find trees with fruit, how to find water during droughts, and other information for survival. This knowledge is passed on to the younger females in her family and eventually one of them will become the matriarch.

In captivity, an elephant can learn to perform a variety of tasks and tricks. Training methods differ. Some training is brutal, with trainers beating the elephant with sharp instruments and eventually breaking its will. Other trainers have tried more gentle methods and have had good results. Elephants are fast learners. A well-trained working elephant may know as many as 40 voice commands.

The life of an elephant

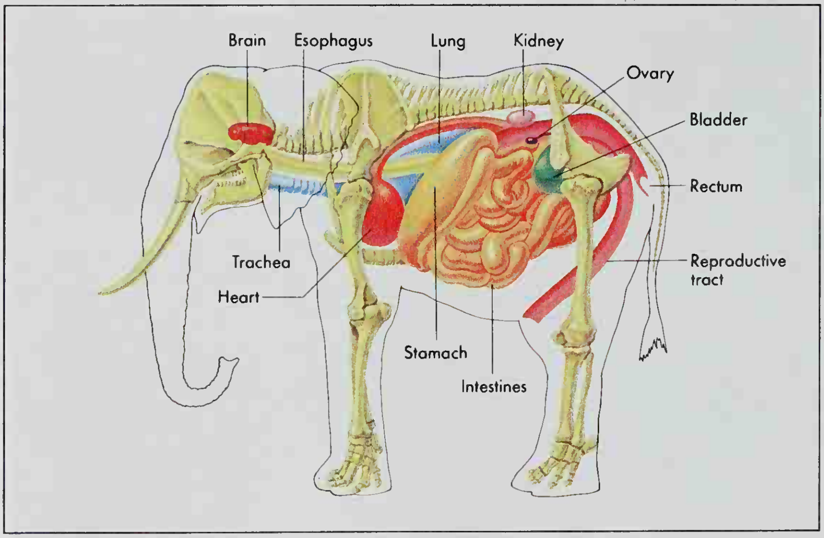
Elephant families. Adult males and females live separately most of the time. The cows and their babies, called *calves,* live in family units averaging about 10 members each. Families consist of three or four related adult females and their offspring, which range from newborn calves to calves up to about 12 years old. Each family is led by the oldest female, the matriarch. Males leave the family as they become adults. Adult males form loose bonds with other males and only visit the family groups occasionally.

A *population* of elephants is made up of all the family groups and independent adult males that share one area. Populations vary in size from a few hundred elephants to several thousand. Each population ranges over a particular area in search of food. In semidesert areas, elephants may have to travel over vast distances to find food. In areas with high rainfall and abundant vegetation, a population may limit itself to as little as 100 square miles (250 square kilometers).

Internal anatomy of a female African elephant

This view of a female African elephant shows the animal's skeleton and some of its internal organs. An elephant's organs resemble those of other mammals but are much larger. For example, an elephant's heart is about 5 times as large as a human heart and more than 50 times as heavy.

WORLD BOOK illustration by James Teason and John D. Dawson



Wild elephants usually eat for about 16 hours every day. They bathe in lakes and rivers and like to roll in muddy water. After a mud bath, an elephant may cover itself with dirt. The dirt coating helps protect the animal's skin from the sun and insects. Elephants often play by tussling among themselves with their tusks and trunks.

Elephants communicate with one another in various ways, including postures, gestures, odors, and, especially, sounds. Elephants make many kinds of rumbling sounds, and each has a different meaning. For example, an elephant calf makes a hoarse, loud rumble when it is frightened, and a mother elephant uses a low, humming rumble to calm her calf. Other sounds made by elephants to communicate include screams, roars, bellows, groans, and squeaks.

Food. Elephants eat grass, water plants, and the leaves, roots, bark, branches, and fruit of trees and shrubs. Using their heads as battering rams, they sometimes knock down small trees to reach the highest leaves. An elephant can knock down a tree that measures 30 feet (9 meters) in height and has a diameter of almost 2 feet (61 centimeters).

Elephants use their tusks to rip the bark off trees. They also dig up roots and shrubs with their tusks. Elephants especially like bamboo, berries, coconuts, corn, dates, plums, and sugar cane. Elephants do not eat the flesh of other animals.

A large adult wild elephant eats about 300 pounds (140 kilograms) of vegetation a day. Wild elephants drink up to 40 gallons (150 liters) of water daily. An elephant can live without water for about three days and may travel as far as 50 miles (80 kilometers) to find it.

Travel. The padded feet of an elephant enable the animal to walk and run with surprisingly little noise. Elephants normally walk at a speed of 3 to 6 miles (5 to 10 kilometers) an hour. When making a long journey, a family walks at about 10 miles (16 kilometers) an hour. An angry or frightened elephant can run more than 25 miles (40 kilometers) an hour, but only for a short distance. An elephant walks and runs with shuffling steps. It cannot jump because of its weight and the structure of its legs.

Peter Davey, Bruce Coleman Inc.

Elephants touch trunks as a greeting. The animals also communicate among themselves by making a variety of low, rumbling noises.

Elephants usually roll in mud or swim at least once a day. They are excellent swimmers and have been known to swim to islands in lakes or off seacoasts. They hold their trunks above water when swimming.

Reproduction. Male elephants reach adulthood when they are 10 to 14 years old. But most do not mate until they are over 30 years old. The main reason for this delay is that older males prevent younger males from mating by chasing them away. In addition, females do not usually accept teen-aged males as mates. Females stay in their family and begin mating at an average age of 12. They may have their first calf at age 13 or 14 and usually produce one every four to five years until well into their 50's.

The female carries her young for 22 months. She almost always has one calf at a time, but twins occasion-

C. Haagner, Bruce Coleman Inc.

Elephants cool off by bathing. They especially like to roll in muddy water. The mud dries on the animal's skin and helps protect it from the sun. An elephant needs water and mud for cooling because its skin has no sweat glands.

Peter Davey, Bruce Coleman Inc.

A baby elephant stays with its mother until it reaches adulthood. The youngster drinks the mother's milk for three to five years. Female offspring stay with the mother until she dies.

ally are born. African elephant calves weigh from 255 to 320 pounds (116 to 145 kilograms) at birth and stand about 3 feet (95 centimeters) tall at the shoulder. Newborn Indian elephant calves weigh about 220 pounds (100 kilograms) and are about $2\frac{4}{5}$ feet (85 centimeters) tall.

A baby elephant can walk less than an hour after birth. Its mother stays close to the youngster and protects it for several years. At first, the calf lives chiefly on the mother's milk. The young elephant drinks the milk by curling its trunk over its head so its mouth can reach the mother's breast. When the calf is 3 to 4 months old, it starts to graze on grass and other plant life. Male calves stay with the mother until they are about 14 years of age. Female offspring remain with the mother until she dies. Elephants grow throughout their lifetime. As a result, the older an elephant is, the bigger it is. Males grow more than females, and a large adult male in his 40's is almost twice the size of a female that age.

Musth. An elephant has a *temporal gland* on each side of its head, about midway between the eye and the ear. About once a year, the temporal glands of large adult males swell and discharge a dark, oily substance that has a strong odor. This substance stains the elephant's face. The temporal glands are active for two or three months yearly. During this period, an elephant is in a condition called *musth* or *must* (both pronounced *muhst*). In the wild, musth usually occurs only in adult male elephants over 25 years old.

While in musth, a captive elephant becomes very dangerous if it gets excited. It may attack nearby animals, including people and other elephants. Elephants in captivity must be chained or caged during musth.

Zoologists are just beginning to understand the role of musth, which occurs periodically at a time when the elephant's body produces more than the normal amount of a hormone called *testosterone*. A male in musth has certain advantages over bulls not in musth. Although elephants also mate when not in musth, the musth male is more aggressive and thus able to fight for and guard a female. A female elephant is more likely to mate with a male in musth. Females are ready to mate during a period of sexual excitement called *estrus,* which lasts about four days at a time.

Protection against enemies. The great size of elephants protects them from almost all other animals. Lions in Africa and tigers in Asia can kill elephant calves, but such instances are rare. When under attack, the elephant family forms a circle around the calves to protect them. An elephant may scare an enemy away by sticking its ears straight out and charging. If an animal attacks, an elephant may crush it to death by stepping on it.

The greatest enemies of elephants are humans. Until modern times, elephants could often protect themselves from hunters by a group defense. Now whole families of elephants can be gunned down by hunters with automatic weapons.

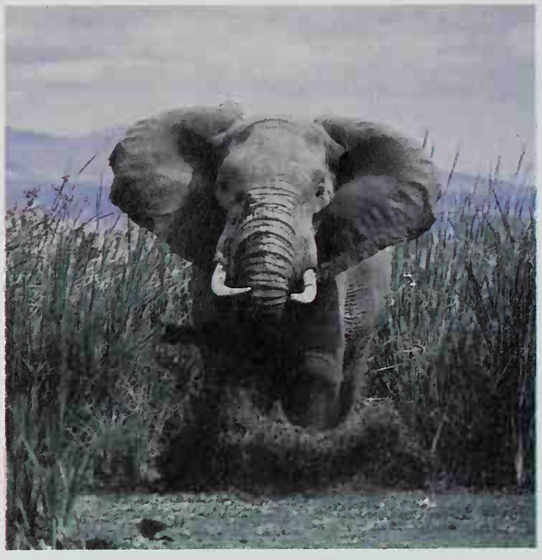
Elephants are easily frightened in areas where they are hunted. A sudden noise, such as a gunshot, can cause a herd to panic. The animals may charge at the source of the noise or stampede away from it. When frightened or excited, elephants sometimes use their trunks to make a loud, shrill cry called *trumpeting.*

Life span. An elephant can live about 65 years. If it does not die from drought or disease or is not killed by hunters, the cause of death will usually be the wearing down of the sixth—and final—set of molars. Once the last set is worn down, the elephant dies of malnutrition.

Some people believe that old elephants go to certain places called "elephant graveyards" to die. This belief may have started because sick or aged elephants tend to go to a part of their range where there is shade and soft vegetation. In these places, people have found the bones of many elephants.

Protecting elephants

Elephants are the only survivors of a group of mammals called *proboscideans.* This group of animals once



Norman Myers, Bruce Coleman Inc.

A charging elephant may make itself look especially dangerous by sticking its ears straight out. Elephants sometimes crush enemies to death by stepping on them.

consisted of more than 350 species, all of which had long snouts or trunks. The earliest known proboscideans lived in Africa and Asia about 50 million years ago. Other proboscideans included the *mammoth* and the *mastodon.* Both animals looked much like the elephant.

Today, wildlife experts agree that elephants are in great danger and need human protection to survive. People have destroyed much of the elephant's natural surroundings by clearing land for settlement and farms.

Many African and Asian nations have set aside land to protect the habitats of elephants and other wild animals. This land lies in national parks and in areas called *reserves.* But some wildlife experts fear that this amount of land is not large enough to save many wild elephants.

Illegal hunting for ivory also threatens the survival of wild elephants. Laws forbid elephant hunting in national parks and in reserves, and they limit the number that sport hunters may kill outside these areas. Sport hunting can usually be controlled, but poachers with automatic weapons can kill thousands of elephants yearly.

The number of African elephants greatly declined in the 1970's and 1980's. As a result, all trade in ivory and other elephant products was banned by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1989. This ban has helped stop the rapid decline of African elephants. In 1997, however, CITES members agreed to allow Botswana, Namibia, and Zimbabwe to sell limited amounts of ivory to Japan. Stockpiled ivory from these three nations was auctioned to Japanese buyers in 1999. Cynthia Moss

Scientific classification. Elephants make up the elephant family, Elephantidae. The African elephant is *Loxodonta africana.* The Indian, or Asian, elephant is *Elephas maximus.*

Related articles in *World Book* include:

Animal	Hannibal	Poaching
Circus	Ivory	Republican Party (picture)
Ear (The ears of animals; picture)	Mammoth	
	Mastodon	

Outline

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V. Protecting elephants

Questions

What is the only animal taller than the elephant?
How have some nations protected elephants from hunters?
How many pounds of food does a wild elephant eat in a day?
How many gallons does a wild elephant drink daily?
What is *musth?* How long does it usually affect an elephant?
What is the length of pregnancy for elephants?
Why do elephants move from place to place?
Why does an elephant cover itself with dirt after bathing?
How do elephants use their tusks?
What is a *matriarch?*

Additional resources

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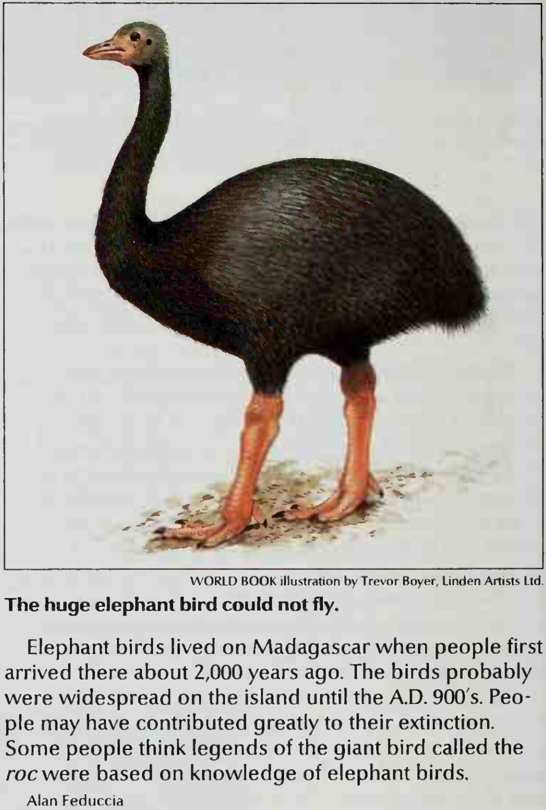
Levine, Stuart P. *The Elephant.* Lucent Bks., 1998. Younger readers.
Shoshani, Jeheskel, ed. *Elephants: Majestic Creatures of the Wild.* Rev. ed. Checkmark, 2000.
Smith, Roland, and Schmidt, M. J. *In the Forest with Elephants.* Harcourt, 1998. Younger readers.

Elephant bird is any one of about seven species of giant extinct birds that once lived on the island of Madagascar. These birds could not fly. The largest was about 10 feet (3 meters) high and weighed about 1,000 pounds (450 kilograms). Eggs that could hold 2 gallons (8 liters) were found with the birds' bones. The eggs were the largest known single cells in any animal.



WORLD BOOK illustration by Trevor Boyer, Linden Artists Ltd.

The huge elephant bird could not fly.

Elephant birds lived on Madagascar when people first arrived there about 2,000 years ago. The birds probably were widespread on the island until the A.D. 900's. People may have contributed greatly to their extinction. Some people think legends of the giant bird called the *roc* were based on knowledge of elephant birds.

Alan Feduccia

Scientific classification. Elephant birds belong to the elephant bird family, Aepyornithidae. They make up the genus *Aepyornis.*

Elephant man's disease. See Neurofibromatosis.

Elephant shrew is a small mouselike mammal with a long, flexible nose. The nose somewhat resembles an elephant's trunk. Elephant shrews are not true shrews but are classified in their own order. They grow from 3 to 12 inches (8 to 30 centimeters) long and weigh $1\frac{1}{2}$ to 19 ounces (42 to 540 grams). They have large eyes and ears, relatively long legs, a long tail, and normally gray or brown fur.

Elephant shrews live throughout much of Africa. They use their long, sensitive nose to find food, which includes insects, spiders, worms, and occasionally plants.

Elephant shrews usually have only one mate for life. In many species, each male and female pair establishes a

© Tom McHugh, Photo Researchers

An elephant shrew has a long, flexible nose that somewhat resembles an elephant's trunk. The animal uses its nose to find food, including insects, spiders, worms, and plants.

territory and defends it together. The male protects the territory from other males, while the female protects it from other females. Female elephant shrews usually give birth to one or two offspring at a time. The young leave their parents after one to two months. Elephant shrews can survive up to four years in the wild. Fred Koontz

Scientific classification. Elephant shrews make up the order Macroscelidea and the family Macroscelididae.

Elephantiasis, *EHL uh fuhn TY uh sihs,* is a skin disease that is most common in the tropics. It gets its name because the affected skin becomes rough and thickened like the hide of an elephant. A tiny worm called *filaria* usually causes the disease (see **Filaria**). Mosquitoes carry the worm. When the mosquito bites, the worm enters the body and eventually lodges in the lymph vessels. A less common form of elephantiasis is caused by the streptococcus bacterium.

Elephantiasis is characterized by fever, roughening of the skin, and swelling of a part of the body, often the leg. There usually is a series of attacks, each increasing the swelling of the affected part. The disease is curable in early stages. However, once the part becomes permanently enlarged, there is no known cure. Drugs and surgery may give relief. Paul R. Bergstresser

Elephant's-ear is a plant with large leaves shaped like an elephant's ear or a shield. There are two common species. In the South Pacific, one type is eaten like potatoes and is also known as *taro, eddo,* and *dasheen.* The elephant's-ear grown in flower beds is similar, but has a smaller root and a more beautiful leaf. See also **Caladium; Taro.** David A. Francko

Scientific classification. The elephant's-ear is in the arum family, Araceae. The scientific name for the ornamental form is *Colocasia antiquorum.*

Eleusinian Mysteries. See Mysteries.

Elevated railroad, usually called an *el,* is an electric railroad that runs on tracks above other traffic. Steel or concrete structures support the tracks. Elevated railroads help lessen traffic on the street level, but they also block some sunlight to the street.

An elevated train gets its power through an electrified third rail, which runs beside the regular rails. Most railcars can propel themselves. A car picks up electric current through two metal plates called *shoes.* The shoes

WORLD BOOK photo by Ralph Brunke

Elevated trains run on tracks above street level and help make city streets less crowded. They operate on electric power.

run along the third rail, delivering current through wires to two *traction motors.* The motors turn *driving wheels,* which propel the car along the track. The car operator uses a device called a controller to regulate the amount of current going to the motors. In a train, the operator uses the controller in the front car to adjust the train's speed. See **Electric railroad.**

Colonel Charles T. Harvey built a one-track experimental elevated line in New York City in 1867. American inventor Rufus Gilbert developed the standard elevated structure used in New York City and Chicago. The first cars were elaborate, with mahogany woodwork, carpeted floors, and plush seats. Robert C. Post

See also **Chicago** (Downtown Chicago; picture).

Elevator is a transportation device that carries people and freight to the floors of a building. The word *elevator* usually means the car in which the people or freight

WORLD BOOK illustration by John D. Dawson

The elephant's-ear plant gets its name from the leaves, which are shaped like a large ear or shield. A favorite Hawaiian dish is made by boiling the starchy underground stems of the plant.

travel. But the term also refers to the entire system that controls the car's movement. The car travels up and down in a shaft that has steel guide rails to prevent movement sideways. In the United Kingdom and some other countries, an elevator is called a *lift.*

The development of elevators led to the construction of skyscrapers. Elevators enabled architects to design taller and taller buildings because people no longer had to climb stairs to reach the upper floors.

Passenger elevators and freight elevators operate in many places and serve a variety of purposes. The passenger elevators commonly seen in office and residential buildings can carry from 2,000 to 4,000 pounds (900 to 1,800 kilograms). Some freight elevators can carry as much as 100,000 pounds (45,000 kilograms).

There are more than 2 million elevators in the world, and about 390,000 of them are in the United States and Canada. Elevators in the United States and Canada carry a total of about 350 million passengers daily.

How elevators work. Most elevators operate automatically. Only a few are run by attendants who ride in the cars. A person brings an elevator to a certain floor by pushing a button in the wall outside the shaft. The elevator doors open automatically after the car arrives at the floor, and they close after the passenger has entered the elevator. The passenger pushes a button to indicate the floor where he or she wants the elevator to stop.

Most elevators in buildings of 10 or more floors are powered by electric traction systems and are lifted by steel cables. There are two types of electric traction elevators, *gearless traction* and *geared traction.*

Gearless traction elevators are used in office buildings of more than 10 floors and in residential buildings of more than 30 floors. They travel at speeds of 400 to 2,000 feet (120 to 600 meters) per minute. Cables called *hoisting ropes* lift the car. One end of each cable is attached to the top of the car. The other end is connected to a heavy steel counterweight that balances the weight of the car and about half of its maximum passenger load. The counterweight reduces to a minimum the power needed to operate the elevator. The hoisting ropes fit around a *sheave* (pulley) that is connected directly to an electric motor. As the sheave turns, the ropes move and the car goes up or down. A brake holds the car in place when the elevator stops.

Geared traction elevators travel at speeds as high as 450 feet (137 meters) per minute. Geared traction elevators are similar to the gearless traction type of elevator. But the motor of a geared traction elevator operates a *reduction gear,* which turns the sheave. This gear decreases the speed at which the sheave turns.

Some elevators, called *hydraulic elevators,* are driven by a hydraulic system. They are moved by a long *ram* (piston) instead of by steel cables. Such elevators travel at speeds of 50 to 150 feet (15 to 48 meters) per minute. They serve many buildings of six or fewer stories. The ram rises and lifts the elevator when an electric pump forces oil into the ram cylinder. The elevator goes down when a valve opens and the oil flows into a storage tank.

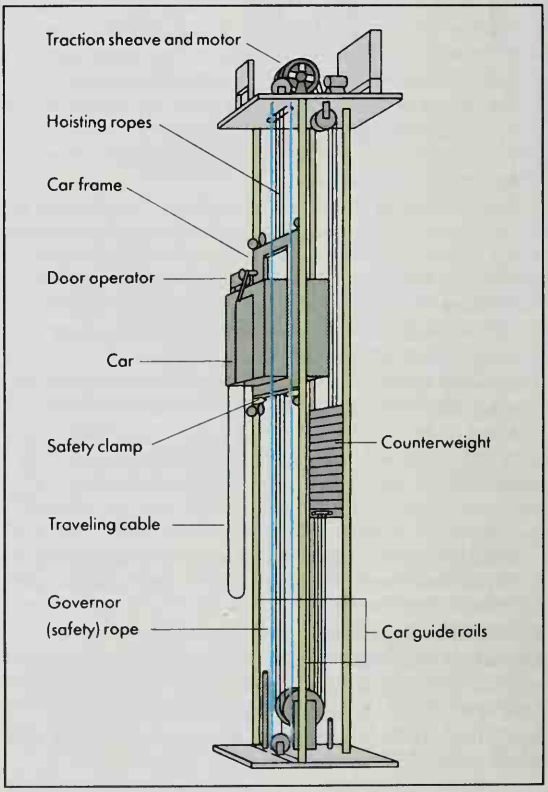
Safety features. Elevators in the United States must operate according to the safety codes of the American National Standards Institute. The institute is an organization of agencies, including consumer, government, and industrial groups. City or state officials inspect elevators regularly to make sure that all the safety features are functioning.

Passenger elevators must have steel doors that can withstand fire. Most have two sets of doors. One set is in the walls at each floor, and the other is part of the car itself. Both sets of doors must close and lock before the elevator can move. A special safety device causes the doors to reopen if someone is in the doorway. If an elevator goes too fast as it travels down, safety clamps grab the guide rails and stop the car. All automatic elevators have alarm bells, and some have intercom systems or telephones. Passengers can use these instruments to call for help if the elevator stops between floors.

Special kinds of elevators. Many large buildings have *double-deck elevators,* which have two compartments and serve two floors with each stop. People who want odd-numbered floors enter the lower compartment on the first floor. People who want even-numbered floors enter on the second floor and ride in the upper compartment. Elevators called *observation elevators* have glass sides and travel along the walls of interior courts or the outside walls of buildings. Passengers can view their surroundings through the glass.

Some tall buildings have express elevators that travel nonstop to certain floors called *sky lobbies,* where passengers change to local elevators. The local elevators then carry the people to their floors.

Construction companies use elevators that travel



WORLD BOOK diagram by Richard Fickle

A gearless traction elevator, *above,* has steel cables called *hoisting ropes* that fit around a sheave. When the sheave is turned by an electric motor, the ropes lift or lower the car.

along the outside of buildings and carry crews and building materials. Other kinds of elevators take workers and materials into mines. Hospital elevators are large enough to carry beds and stretchers.

History. The ancient Greek mathematician Archimedes invented a type of elevator before 230 B.C. It used ropes and pulleys and could lift one person.

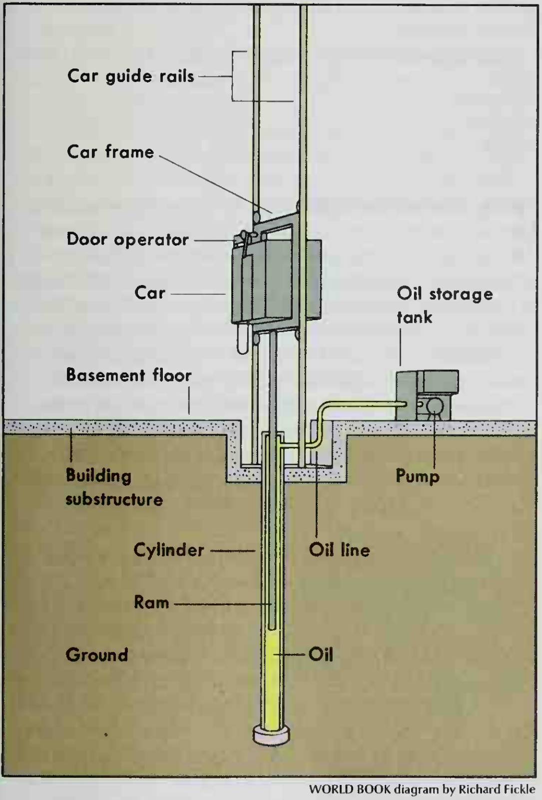
Elevators became common in the United States and England during the early 1800's. By the 1840's, both hydraulic and steam-powered freight elevators had been invented. But the hydraulic elevators were very slow, and the ropes of the steam-powered elevators often broke and the cars fell.

In the early 1850's, Elisha G. Otis of Yonkers, N.Y., invented the first elevator that had an automatic safety device. If the rope broke, the device prevented the elevator from falling. Otis first demonstrated the elevator in 1854. The world's first elevator designed specifically for passenger use was installed in New York City in 1857. The world's first electric elevator started operating in 1889.

Automatic elevators were introduced in residential buildings in the 1890's. Attendants operated the elevators in major office buildings until 1950. That year, an office building in Dallas became the first with automatic elevators. Cynthia J. DiTallo

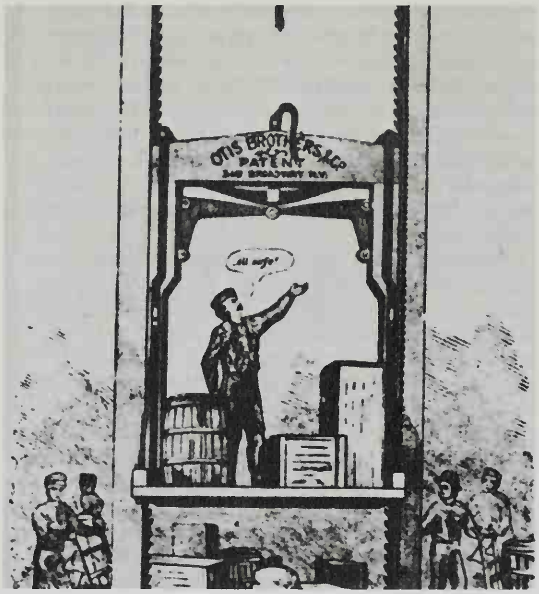
See also Otis, Elisha G.

Elevator, Grain. See Grain elevator.



WORLD BOOK diagram by Richard Fickle

A hydraulic elevator, *above,* is lifted and lowered by a *ram* (piston). The car rises when a pump forces oil into the ram cylinder. The car descends when the oil flows into a storage tank.



Historical Pictures Service

The first elevator with a safety device was demonstrated by Elisha G. Otis in 1854. The automatic device prevented the elevator from falling if the hoisting rope broke.

Eleventh Amendment. See Constitution of the United States (Amendment 11).

Elf is an imaginary creature in northern European folklore. In some cultures, elves are called fairies. In most folk tales, elves are tiny people. However, in a few folk traditions, elves are the same size as human beings. Many folk tales describe elves as merry beings who enjoy singing and dancing all night in meadows.

Elves possess magical powers. Like other fairy creatures such as leprechauns and pixies, elves can perform good deeds, but they can also cause misfortune, especially when they are offended. Many British and Scandinavian folk tales describe how elves steal animals and human children or lead travelers astray in forests. Elves sometimes make farm animals ill by shooting them with tiny arrows called "elf-shot." But elves can also be generous. They may grant good luck or a pocketful of gold to someone they like. C. Scott Littleton

See also Fairy; Gnome.

Elgar, Sir Edward William (1857-1934), a British composer, became best known for his *Pomp and Circumstance,* a set of five marches. He adapted the famous theme of the first *Pomp and Circumstance* march as the official ode for the coronation of King Edward VII in 1902. The composition generally called Elgar's masterpiece is the oratorio *The Dream of Gerontius* (1900), based on a poem by John Cardinal Newman. Elgar also became known for *The Enigma Variations* for orchestra (1899), and *Introduction and Allegro* for strings (1905). In his compositions, Elgar showed a strong sense of the harmonies and musical forms of the romantic era.

Elgar was born near Worcester, England, and was largely self-taught in composition. He wrote a number of choral works, including *The Black Knight* (1893), *The Apostles* (1903), *The Kingdom* (1906), and *The Spirit of*

England (1916). Other successful works are the *Cockaigne* overture (1901), two symphonies, a violin concerto, and a cello concerto. Mary Vinquist

Elgin, *EHL gihn,* **Earl of** (1811-1863), served as governor general of Canada from 1847 to 1854. He is best known for recognizing the establishment of *responsible government* in Canada. Under this practice, Canada would be governed by a ministry that had the confidence of the legislature, rather than by agents of the British government.

Elgin was born in London. His given and family name was James Bruce. The eighth Earl of Elgin, he was educated at Eton and at Oxford University. He was elected to the House of Commons in 1841. From 1842 to 1846, he served as governor of Jamaica.

As governor general of Canada, Elgin was instructed by the British colonial secretary to accept responsible government. Elgin then called upon French and English Canadian reformers who had won a majority of seats in the 1848 election to form an administration. In 1849, the reformers passed the Rebellion Losses Bill. This bill was designed to compensate both rebels and loyalists who had suffered as the result of a rebellion in 1837 and 1838. Elgin approved the bill. Conservative opponents of the bill then burned the parliament buildings and stoned Elgin's carriage. Although in serious danger, Elgin refused to change his position. D. Peter MacLeod

Elgin Marbles, *EHL gihn,* are a group of ancient Greek sculptures that originally decorated the Acropolis in Athens. They are named for Lord Elgin, a British ambassador to Constantinople, who collected them between 1802 and 1804. Most of the sculptures were part of the Parthenon. They include 56 slabs from the *frieze,* a band of horizontal relief sculpture around the top of the temple. The collection also includes statues that once stood in the *pediments* (triangular segments of the roof) and 15 slabs from the *metopes* (square panels in the frieze above the columns). The collection also contains a *caryatid* (column in the form of a statue of a woman) from the Erechtheum, another temple on the Acropolis.

In 1801, Lord Elgin received permission from the Turkish government to remove the sculptures from Greece. Greece was then part of the Turkish Empire. From 1803 to 1812, Elgin shipped his collection to England. The British government purchased the Elgin Marbles in 1816 for the British Museum. Marjorie S. Venit

See also **Acropolis; Parthenon.**

El Greco. See Greco, El.

Elijah, *ih LY juh,* was an Israelite prophet who lived in the 800's B.C. Much information about him appears in I and II Kings of the Old Testament. Elijah is also mentioned 29 times in the New Testament.

Elijah was born in Tishbe in what was then northern Israel. He gained fame as a miracle worker. For example, he miraculously increased the scarce supply of food for a poor widow (I Kings 17:8-16) and brought the widow's dead son back to life (I Kings 17:17-24). Elijah also used his powers to prove the greatness of God. He opposed King Ahab and his wife Queen Jezebel because they abandoned the *covenant* (agreement) with their God and supported the worship of the heathen god Baal. Elijah won a contest on Mount Carmel against the prophets of Baal, convincing the people of Israel of the superiority of their God (I Kings 18:17-39). Just before his death, Elijah transferred his role as a prophet to his disciple Elisha, and then ascended to heaven in a whirlwind (II Kings 2:1-15). Later references to Elijah in the Bible mention or suggest that he will return to announce the coming of the Messiah. Carol L. Meyers

Elijah Muhammad. See Muhammad, Elijah.

Elimination, also called *excretion,* is the process of removing water, waste matter, and harmful substances from the body. The skin, lungs, kidneys, and lower intestinal tract carry out this function. The kidneys eliminate most of the excess water and salt. However, an average of about 1 quart (0.95 liter) of water and $\frac{1}{3}$ teaspoonful (1.6 milliliters) of salt are eliminated through the skin every day. When visible sweating occurs, the elimination of water and salt by the skin may be much greater. Perspiration withdraws from the body about one-fourth of all the heat produced.

The process of respiration eliminates carbon dioxide and some water. An adult eliminates about 6 $\frac{4}{5}$ ounces (200 milliliters) of carbon dioxide each minute.

Many different substances pass out of the body through the kidneys. They eliminate daily about 1 $\frac{1}{2}$ quarts (1.4 liters) of urine, consisting of water and certain solids. Urine contains the solid *urea,* a waste product of the use of protein by the body. Another solid is salt, or sodium chloride. Elimination of certain acid salts, such as acid sodium phosphate, also takes place. Excess *sodium bicarbonate* (baking soda) is sometimes eliminated in the urine by the kidneys. The body rids itself of waste products of digestion through the large intestine.

Jeffrey R. Woodside

Related articles in *World Book* include:

Colon	Perspiration
Colostomy	Urea
Intestine	Uric acid
Kidney	Urine
Lung	

Elion, Gertrude Belle (1918-1999), an American biochemist, helped create important drugs used to treat cancer, malaria, and other deadly diseases. Elion worked with American biochemist George H. Hitchings at a research division of the Burroughs Wellcome Company. Elion and Hitchings studied how growth and reproduction in diseased cells and viruses differ from these processes in normal cells. They reasoned that identifying such differences would reveal ways to destroy unwanted cells without harming normal ones. In 1988, Elion and Hitchings shared the Nobel Prize in physiology or medicine with British scientist James W. Black for developing such logical new approaches to drug design.

In the 1950's, Elion and Hitchings designed a drug called *mercaptopurine (mur KAP toh PYUR een).* Mercaptopurine was the first drug effective in treating leukemia, a cancer in which white blood cells multiply wildly. The pair then created a related drug that helps prevent rejection of transplanted organs. In the 1960's, Elion's team developed the drug *acyclovir (ay SY kloh vihr),* the first antiviral drug used to treat genital herpes.

Elion was born and raised in New York City. She earned bachelor's and master's degrees in chemistry at New York City colleges. When she looked for work, many prospective employers refused to employ a woman chemist. After World War II pulled men away

from their jobs and into combat, she was hired at Burroughs Wellcome in 1944. After her retirement, Elion served in prominent scientific advisory positions. She became a member of the National Academy of Sciences in 1990 and received the National Medal of Science in 1991. David F. Musto

Eliot, Charles William (1834-1926), an American educator, served as president of Harvard University for 40 years, from 1869 to 1909. He did much to shape the program and standards of liberal and professional education in the United States. Eliot brought outstanding scholars to Harvard as teachers and established elective courses there. He also reorganized the administration of the university and added a number of graduate and professional colleges.

Eliot served as chairman of the National Education Association's Committee on Secondary School Studies (Committee of Ten). This committee recommended an academic rather than vocational program of study for all high school students. The recommendation strongly influenced secondary education in the United States.

Eliot was born in Boston and studied at Boston Latin Grammar School and Harvard University. He taught mathematics and chemistry at Harvard from 1858 to 1863 and then studied in Europe for two years. He taught at the Massachusetts Institute of Technology for four years and then returned to Harvard as its president. Eliot was a member of the General Education Board and a trustee of the Rockefeller Foundation and the Carnegie Foundation. He wrote widely on educational subjects.

Glenn Smith

Eliot, George (1819-1880), was the pen name of Mary Ann (or Marian) Evans, a great English novelist. Much of her fiction reflects the middle-class rural background of her childhood and youth. George Eliot wrote with sympathy, wisdom, and realism about English country people and small towns. She wrote seriously about moral and social problems, but her characters are living portraits.

George Eliot's masterpiece, *Middlemarch: A Study of Provincial Life* (1871-1872), is a long story of many complex characters, and their influence on and reaction to each other. *Adam Bede* (1859), her first novel, is a tragic love story in which her father serves as the model for the title character. *The Mill on the Floss* (1860) and *Silas Marner* (1861) are somber works set against country backgrounds. *Silas Marner* is the story of an embittered old miser who loses his gold, but turns to a more human life through his love for a little girl. *Romola* (1863) is a historical novel set in Renaissance Florence. *Felix Holt, Radical* (1866), George Eliot's only political novel, is considered one of her poorer works. *Daniel Deronda* (1876), her last novel, displays the author's knowledge of and sensitivity to Jewish culture. The book is notable for the warm portrait of its heroine, Gwendolen Harleth.

Culver

George Eliot

George Eliot was born in Warwickshire. She received an excellent education in private schools and from tutors. After her father's death in 1849, she traveled in Europe and then settled in London. There she wrote for important journals and became a friend of many important people. British intellectuals regarded her as one of the leading thinkers of her day. George Eliot lived with the writer George Henry Lewes from 1854 to 1878, although Lewes was married and could not obtain a divorce under existing law.

Sharon Bassett

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Eliot, John (1604-1690), was an American missionary to the Indians of Massachusetts. He translated the Bible into an Indian dialect. Eliot was born in Hertfordshire, England, and came to America in 1631. He was made the teacher of the church in Roxbury, Massachusetts. Eliot organized the first village of Indian converts at Natick, near Boston, in 1651. By 1674, he had 14 villages with more than 1,000 Indians under his supervision. But King Philip's War (1675-1676) scattered his converts.

Charles H. Lippy

Eliot, T. S. (1888-1965), ranks among the most important poets of the 1900's. In "The Love Song of J. Alfred Prufrock," *The Waste Land,* and other poems, he departed radically from the techniques and subject matter of pre-World War I poetry. His poetry, along with his critical works, helped to reshape modern literature. Eliot received the 1948 Nobel Prize for literature.

His life. Thomas Stearns Eliot was born in St. Louis. He studied at Harvard, the Sorbonne in Paris, and Oxford. He settled in London in 1914. Eliot was working as a bank clerk when his poems came to the attention of the American poet Ezra Pound. Pound encouraged Eliot and helped him with his poetry.

Many of Eliot's views on literature appeared in *The Criterion,* a literary magazine he edited from 1922 to 1939. Eliot served as a director of a London publishing house from 1925 until his death.

In 1927, Eliot became a British subject, declaring himself "Anglo-Catholic in religion, royalist in politics, and classicist in literature."

His works. Eliot's first major poem, "The Love Song of J. Alfred Prufrock" (1917), revealed his original and highly developed style. The poem shows the influence of certain French poets of the 1800's, but its startling jumps from rhetorical language to cliché, its indirect literary references, and its simultaneous humor and pessimism were quite new in English literature.

"Prufrock" created a small literary stir, but *The Waste Land* (1922) created an uproar. Some critics called the work a masterpiece, others a hoax. While this long, complex poem includes many obscure literary references, many in other languages, its main direction is clear.

Kay Bell

T. S. Eliot

It contrasts the spiritual bankruptcy Eliot saw in modern Europe with the values and unity of the past.

Eliot's "Ash Wednesday" (1930), far different from *The Waste Land* in tone and mood, is more musical, direct, and traditional, and, in its religious emphasis, tentatively hopeful. *Four Quartets,* his last major poem, is a deeply religious, often beautiful, meditation on time and timelessness. It includes four sections: "Burnt Norton" (1936), "East Coker" (1940), "The Dry Salvages" (1941), and "Little Gidding" (1942). In "Little Gidding," he wrote:

> We shall not cease from exploration
> And the end of all our exploring
> Will be to arrive where we started
> And know the place for the first time.

Eliot also wrote several verse dramas. *Murder in the Cathedral* (1935), his first major play, is based on the death of Thomas Becket. On the surface, *The Cocktail Party* (1950) appears to be a sophisticated comedy, but it is really a deeply religious and mystical work. Eliot's other plays include *The Family Reunion* (1939), *The Confidential Clerk* (1954), and *The Elder Statesman* (1958).

Eliot's *Complete Poems and Plays (1909-1950)* was published in 1952. *Selected Essays* (3rd edition, 1951) is a collection of his important prose. William Harmon

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Elisha, *ih LY shuh,* was the follower, servant, and later the successor of the Hebrew prophet Elijah. Elisha was active from about 850 to 800 B.C., carrying on his master's policies against the pagan religion favored by King Jehoram of Israel. With this purpose, he encouraged Jehu to rebel and seize the throne. Many stories are told about Elisha in II Kings, chapters 2-9. One story describes Elisha parting the Jordan River with Elijah's mantle. Others tell how he healed the commander of the Syrian army, revived a Shunammite woman's dead son, and fed 100 men with only 20 loaves of barley and some ears of corn. Gary G. Porton

See also Elijah.

Elissa. See Dido.

Elizabeth, New Jersey (pop. 120,568), is the oldest English settlement in the state. It lies in the eastern part of New Jersey, 12 miles (19 kilometers) southwest of New York City (see New Jersey [political map]). It is a manufacturing, transportation, and service center. Its factories make clothing, fabricated metal products, industrial machinery, paper products, pharmaceuticals, and rubber products. Its port is a major port for container ships.

Elizabeth was settled in 1664 after England gained control of the Dutch colonies in North America. Philip Carteret (1639-1682), first English governor of New Jersey, selected the settlement as the site for his capital. He called it *Elizabethtown.* The city's industrial development began after 1835 when some New York businessmen bought land bordering Staten Island Sound, on which to build manufacturing plants. Elizabeth also became a major railroad center. The Goethals Bridge, which connects Elizabeth with Staten Island, opened in 1928. Elizabeth has a mayor-council government. It is the seat of Union County. Paul G. E. Clemens

Elizabeth, Queen Mother of England. See George VI; Elizabeth II.

Elizabeth, Queen of the Belgians. See Albert I.

Elizabeth I (1533-1603) was queen of England from 1558 until her death in 1603. Her reign is often called the Golden Age or the Elizabethan Age because it was a time of great achievement in England. Elizabeth made the Church of England, a Protestant denomination, the country's main church. At the same time, she long avoided war with Europe's leading Roman Catholic nations. The English navy defeated a powerful Spanish fleet, and English merchants and sailors challenged the Spaniards with greater confidence around the world. England's economy also prospered. Elizabeth's court became a center for musicians, writers, and scholars.

Elizabeth was a strong and clever ruler, and she succeeded in furthering England's interests despite foreign threats and religious unrest at home. Elizabeth gained the loyalty and admiration of her subjects. She reminded them of her popular father, King Henry VIII. The queen had his red hair and pale eyes. She also shared her father's gifts for music and other arts. In addition, she was an outstanding orator.

Early years. Elizabeth was born on Sept. 7, 1533, at Greenwich, an estate near London. She was the daughter of Henry VIII and his second wife, Anne Boleyn. Elizabeth's mother was executed on a charge of adultery in 1536. Henry died in 1547 and was succeeded by Elizabeth's half-brother, Edward VI. Like Elizabeth, Edward had been raised a Protestant. When he died in 1553, Elizabeth's half-sister, Mary Tudor, became queen. Mary had been raised as a Catholic by her mother, Catherine of Aragon. Catherine was the first wife of Henry VIII. Mary was determined to make Catholicism the state religion of England. She became known as "Bloody Mary" for her persecution of Protestants. See Mary I.

Queen Mary distrusted Elizabeth, who was next in line to the throne. Elizabeth cautiously avoided any involvement in politics during Mary's rule. However, Elizabeth came under suspicion in 1554, following an uprising known as Wyatt's Rebellion. The rebels tried to overthrow Mary, but they failed. Elizabeth was imprisoned for a time, though no evidence was found that linked her to the rebellion. Mary died in 1558, and Elizabeth became queen.

Problems at home and abroad challenged Elizabeth as queen. The previous year, Mary had involved England in a costly war with France. Struggling Protestant forces in Scotland, France, and the Netherlands sought Elizabeth's support. But, England's economy was poor, and the treasury lacked the revenue to support the routine costs of government. Elizabeth also had to decide whether England's religion would be Catholic or Protestant and to do so without causing a revolt.

With the aid of Parliament and her chief adviser, Sir William Cecil, Elizabeth ended the war with France. She also secretly sent money and weapons to the Scottish Protestants. Elizabeth hoped to satisfy most of her subjects by establishing a church that was primarily Protestant in doctrine. Elizabeth therefore signed several laws called the Religious Settlement of 1559. The main law, the Act of Supremacy, reestablished the Church of Eng-

land, which her father set up and Mary tried to abolish. This church was independent of the Roman Catholic Church, but had similarities to it. The Act of Uniformity approved a new prayer book and enforced the book's use.

Elizabeth never married, and she used her single status as a foreign policy tool. She encouraged both Catholic and Protestant suitors, but committed herself to no one. By avoiding marriage to a Protestant, she gave encouragement to her own Catholic subjects, who remained loyal with few exceptions. Elizabeth's flirtations with Catholic suitors kept King Philip II of Spain, a Catholic, from taking direct military action against her for several years while the Church of England gained popular support. For a time, Elizabeth seemed to be in love with one of her subjects, Sir Robert Dudley, the Earl of Leicester. However, Elizabeth's cautious nature kept her from entering a marriage that lacked political benefit.

Mary, Queen of Scots. Elizabeth's cousin, Mary Stuart, was forced to abdicate her throne as queen of Scotland in 1567. She later fled to England, where her presence caused uneasiness. Mary was a Catholic and heir to the English throne. Many English people feared she would try to replace Elizabeth. Several plots against Elizabeth involving Catholic nobility proved unsuccessful. In 1584, the English aristocracy formed an association to protect their queen and vowed to prevent a Catholic succession in England. In 1586, Mary was implicated in another plot against Elizabeth. Public reaction against Mary was strong. Elizabeth finally, though reluctantly, agreed to Mary's execution in 1587.

The Spanish Armada. In 1585, Elizabeth sent an army to help Protestants in the Dutch Netherlands fight Spanish rule. She also encouraged English ships to raid Spanish fleets. Sir Francis Drake, Sir Walter Raleigh, and other "sea dogs" looted several Spanish ships. In 1587, Drake destroyed 30 Spanish ships in port at Cádiz. These events and the execution of Mary Stuart led King Philip II of Spain to approve an invasion of England. He assembled an armada and sent it to England in 1588. But the smaller and swifter English vessels routed the Spanish fleet. Fierce storms then wrecked many of the fleeing Spanish ships off the coasts of Ireland and Scotland. Spain's power was seriously damaged, but the war went on for 16 years. See **Spanish Armada.**

A new optimism. Despite the armada's defeat, many English people still feared a Spanish invasion. But Elizabeth eased their fears in August of 1588 with a speech to soldiers assembled at Tilbury. Her words stirred national pride and confidence and scorned any European power who dared to invade England. Her optimism was typical of one of the most creative and productive periods in England's history. English literature, in particular, thrived during this period. Francis Bacon composed his *Essays*; Christopher Marlowe wrote and staged *The Tragical History of Doctor Faustus*; Edmund Spenser wrote his epic poem, *The Faerie Queene*; and William Shakespeare wrote some of the world's greatest poetry and drama (see **English literature** [The beginning of modern English]; **Shakespeare, William**). Already Sir Walter Raleigh had sent settlers to America, opening the way for a great colonial empire.

Later years. Problems at home marked the end of Elizabeth's reign. The Irish rebelled, and the economy

Oil painting on canvas; the Marquess of Salisbury, Hatfield House

Queen Elizabeth I ruled England from 1558 to 1603. The English artist Nicholas Hilliard painted this portrait in 1585.

soured. The Earl of Essex had captured Elizabeth's interest, but he became discouraged in his quest for power and led a rebellion against the government in 1601. He was soon captured, convicted of treason, and executed. Elizabeth was succeeded by James VI, the Protestant son of Mary Stuart. Arthur J. Slavin

See also **England** (picture); **Furniture** (England); **Henry VIII; Leicester, Earl of.**

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Elizabeth II (1926-) is the queen of the United Kingdom of Great Britain and Northern Ireland. She became queen when her father, King George VI, died in 1952. As a *constitutional monarch,* Queen Elizabeth is formally head of state in the United Kingdom. But she has no power over what the British government does. Laws are formally enacted in the name of the queen, but their content is the responsibility of the government.

Early life. Elizabeth Alexandra Mary was born in London on April 21, 1926. Her father was the Duke of York, second son of King George V. Her mother—Queen Elizabeth, the Queen Mother—was the former Lady Elizabeth Bowes-Lyon, the daughter of a Scottish earl.

Elizabeth's father became king in 1936 after his older brother, King Edward VIII, gave up the throne to marry a divorced American woman. This event greatly changed the course of 10-year-old Elizabeth's life. It made her the heir to the throne, since George VI had no sons and she was the older of his two daughters.

Princess Elizabeth spent most of her childhood at

Windsor Castle, located in Windsor, near London. The castle is the British royal family's main residence outside of London. Buckingham Palace, in London, is the family's main residence. Princess Elizabeth and her sister, Princess Margaret (1930-2002), were educated at home by governesses. In March 1945, during World War II, Elizabeth joined the Auxiliary Territorial Service, a support branch of the military. She joined to train as a mechanic to repair military vehicles for the war effort. But Elizabeth served only until May, when the war in Europe ended.

Marriage and succession to the throne. Princess Elizabeth married Philip Mountbatten, a British naval lieutenant and member of the Greek royal family, on Nov. 20, 1947. Her husband became Prince Philip, Duke of Edinburgh. When King George's health began to fail, Princess Elizabeth and her husband began to undertake more public duties. The king died on Feb. 6, 1952, and Princess Elizabeth succeeded him as the British monarch that day. The coronation of Queen Elizabeth II took place on June 2, 1953, in Westminster Abbey, London.

Duties. After a general election, the queen formally appoints the prime minister. In practice, this person is the leader of the majority party in the democratically elected House of Commons. The queen has a weekly meeting with the prime minister to discuss public affairs. The prime minister is not obligated to act on her advice, but may find it useful because of her many years of experience.

The queen's chief public role is to attend ceremonial state occasions and to represent the United Kingdom in visits throughout the country and the world. Queen Elizabeth has traveled extensively. In the United Kingdom, the queen sometimes puts ceremony aside and meets informally with subjects. She hosts luncheons at Buckingham Palace, which are attended by people of many different walks of life.

The queen is also head of the Commonwealth of Nations, an association of independent countries and other political units that have lived under British law and government. Queen Elizabeth has no authority in Commonwealth nations. She serves mainly as a symbol of historical ties.

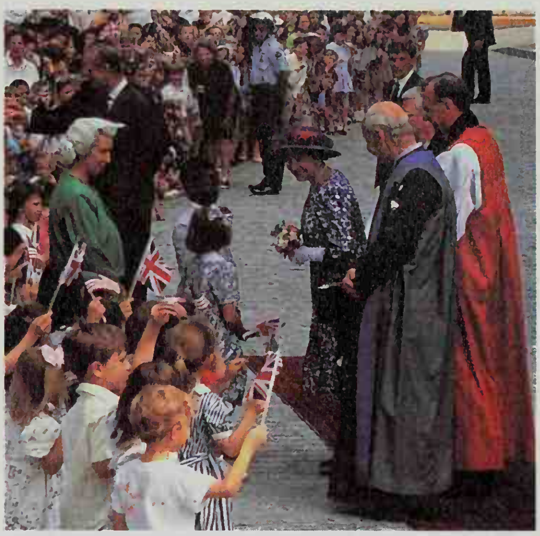
The royal family. The queen and Prince Philip have four children. The children are Charles, Prince of Wales (1948-   ); Anne, Princess Royal (1950-   ); Andrew, Duke of York (1960-   ); and Prince Edward (1964-   ). Prince Charles is heir to the throne. His oldest son, Prince William (1982-   ), is next in line after his father as the heir. The royal family's surname is Windsor. However, in 1960, Queen Elizabeth announced that her descendants, except for princes and princesses, will bear

Fox Photos Ltd.

The coronation of Queen Elizabeth II, *shown here,* was a colorful ceremony that took place on June 2, 1953. Elizabeth had become the British monarch about 16 months earlier—on Feb. 6, 1952.

British Information Service

Queen Elizabeth II serves as the monarch of the United Kingdom and as the head of the Commonwealth of Nations.



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The queen has traveled widely during her reign. This scene shows her on a visit to the United States in 1991.

the surname Mountbatten-Windsor.

The royal family has two country residences. One is Balmoral Castle in Grampian Region, Scotland. The other is Sandringham, an estate in Norfolk County, England. Queen Elizabeth enjoys country life and breeds dogs and horses. She has owned successful race horses.

Richard Rose

See also **Charles, Prince; Philip, Prince; United Kingdom** (Government; picture); **Windsor.**

Elizabeth, Saint, according to Luke 1, was the mother of Saint John the Baptist and a kinswoman of Mary. In Luke's account, when both Elizabeth and her husband, Zechariah, were advanced in years, the angel Gabriel appeared to Zechariah and predicted that his wife would bear a son to be called John. Mary visited her at her home in Judea before the birth of Jesus. Elizabeth's feast day is November 5. J. H. Charlesworth

See also **John the Baptist, Saint.**

Elizabethan Age. See **Elizabeth I.**

Elizabethan theater. See **Shakespeare, William; Drama** (Elizabethan, Jacobean, and Caroline drama); **Globe Theatre.**

Elk is the name of two members of the deer family. One kind of elk lives in North America. The other lives in Europe and looks like the American moose.

The American elk. The Shawnee Indians and the scientists of later times called the American elk the *wapiti.* The animal was given the name of *elk* by the early English colonists. They paid no attention to the fact that the name *elk* had long been used for the European moose. Nevertheless, the name stuck, and is still most commonly used.

The American elk is much like the red deer found in Europe and Asia. It is smaller than the European elk (European moose). The *bull* (male) elk stands about 5 feet (1.5 meters) high at the shoulder, and may weigh from 700 to 1,100 pounds (320 to 500 kilograms). Its rounded antlers may spread more than 5 feet (1.5 meters). The antlers of a grown bull will have a total of about 12 points. Antlers grow during the summer and they are shed in late winter. The *cow* (female) is smaller than the male, and has no antlers. Elk are brownish-gray with a yellowish-tan rump. The legs, head, and neck are dark brown.

During September and October, the bulls fight for leadership in the herd. An exceptional bull may keep a harem of 60 or more cows, but the average one keeps only a dozen or so cows at a time. As the elk travel from high mountain valleys called *parks* to the lower valleys, they gather into large herds of both sexes and all ages. In the lower valleys, where the snow is not too deep, they spend the winter.

In the spring, the elk move slowly back into the higher mountains. The calves are born in May or June. A cow

Michael Ederegger from Peter Arnold

The American elk has dark brown fur on its legs, head, and neck. Each summer, males of this North American species grow antlers that may spread more than 5 feet (1.5 meters).

rarely bears more than one calf. An elk calf is light tawny-brown, with many white spots that are lost during the first change of coat in August.

Elk usually eat grasses. They also eat the twigs and needles of fir, juniper, and many hardwood trees and shrubs, especially during the winter. Many of the larger elk herds of the United States and Canada do not have enough winter range for feeding. Many elk die of starvation or from diseases, such as pneumonia and *necrotic stomatitis* (calf diphtheria). Wolves and cougars are among the natural enemies of elk. Bears and coyotes kill some calves and sick adults.

Elk were once found over most of the United States and southern Canada. But hunters killed so many of them that they survived only in the region west of the Rocky Mountains. Some elk have been brought back to several regions, including parts of New Hampshire, Pennsylvania, Virginia, Michigan, South Dakota, New Mexicó, and Arizona. The largest herds live in Yellowstone Park, on Montana's Sun River, and in Washington's Olympic Mountains.

The European elk is the largest European deer. It belongs to the same *species* (kind) as the huge, awkward American moose, with its scoop-shaped antlers. During the Middle Ages, Scandinavians sometimes used elk as beasts of burden. But reindeer later took the elk's place.

Elk have been well protected by law in European countries, but the animals are gradually dying out in Europe. Some elk still live in parts of eastern Europe and in the forests of Norway, Sweden, and northeastern Germany. A Eurasian type of elk ranges eastward across Siberia, Manchuria, and Mongolia.

Another species of deer, the *Irish elk,* is extinct. It probably belonged to the fallow deer family. The Irish elk was immense. The species was distinguished by its huge antlers, which sometimes measured 11 feet (3 meters) from tip to tip.

The Altai wapiti and Manchurian wapiti of Asia are the largest of all the red deer. But these species do not have such huge antlers as the wapiti of America.

Gregory K. Snyder

Scientific classification. Elk are members of the deer family, Cervidae. The scientific name for the American elk is *Cervus elaphus.* The European elk is *Alces alces.*

See also **Deer; Moose; Red deer; Reindeer.**

Elks, Benevolent and Protective Order of, is a fraternal and charitable organization. It has approximately 1,450,000 members in about 2,300 lodges in the United States and its territories.

Each year, the Benevolent and Protective Order of Elks contributes more than $50 million to hospitals, youth activities, home therapy for disabled children, and entertainment at veterans' hospitals. The Elks National Foundation offers grants for scholarships, the study of cerebral palsy, and other health and youth activities.

The Elks National Home at Bedford, Virginia, is a home for retired Elks members. Elks headquarters are in Chicago.

Critically reviewed by the Benevolent and Protective Order of Elks

Ellery, William (1727-1820), was one of the Rhode Island signers of the Declaration of Independence. He served in the Continental Congress from 1776 until 1781 and in the Congress of the Confederation from 1783 until 1785. He became commissioner of the Continental Loan Office for Rhode Island in 1786. He was collector of customs at Newport from 1790 until his death. William Ellery was born on Dec. 22, 1727, in Newport, Rhode Island. Gary D. Hermalyn

Ellesmere Island, *EHLZ meer,* is part of Canada's territory of Nunavut. It lies west of Greenland. It covers 75,767 square miles (196,236 square kilometers) and is the world's 10th largest island. It has a population of more than 100. Smith Sound and Kennedy Channel separate it from Greenland. The Prince of Wales Mountains rise in eastern Ellesmere. In 1616, William Baffin became the first European to reach the island. Robert Peary explored it in 1899. See also **Arctic Ocean** (map); **Baffin, William; Peary, Robert E.** M. Donald Hancock

Ellice Islands. See **Tuvalu.**

Ellington, Duke (1899-1974), was an American jazz bandleader, composer, and pianist. He rates as one of the greatest figures in jazz and, according to many critics, its most significant composer.

Edward Kennedy Ellington was born on April 29, 1899, in Washington, D.C. He began playing piano at the age of 7 and made his professional debut at 17. He moved to New York City in 1923 as a member of Elmer Snowden's band, the Washingtonians. Ellington soon took over the band, which grew from 5 pieces to 12 pieces by 1931. From 1927 to 1932, the Ellington band was the house band at the Cotton Club in Harlem. There, they played a rhythmic, exotic sound called *jungle music.*

The band's reputation gradually grew through many recordings of Ellington compositions, including "Mood Indigo" (1930), "Creole Rhapsody" (1931), "It Don't Mean a Thing If It Ain't Got That Swing" (1932), "Sophisticated Lady" (1933), "Solitude" (1934), and "In a Sentimental Mood" (1935). The mid-1930's to the mid-1940's is generally considered Ellington's most creative period. Many of his most highly regarded recordings were made during this time, including "Harlem Air-shaft" (1940), "Jack the Bear" (1940), "Ko-Ko" (1940), and "Concerto for Cootie" (1940). In 1939, Billy Strayhorn joined Ellington's band as a composer, often with Ellington, and arranger. He composed "Take the A Train" (1941), which became the band's theme song.

Down Beat Magazine

Duke Ellington, *center,* was one of the leading figures in jazz history. For almost 50 years, he led an orchestra that featured many of the finest soloists in jazz. They included alto saxophonist Johnny Hodges, *left,* and clarinetist Jimmy Hamilton, *right.*

Many of Ellington's key musicians—such as saxophonists Johnny Hodges and Harry Carney—stayed with him for several decades, contributing to the band's readily identifiable sound. Other important musicians were tenor saxophonists Ben Webster and Paul Gonsalves, trombonists Joe Nanton and Lawrence Brown, clarinetist Barney Bigard, bassist Jimmy Blanton, and trumpeters Rex Stewart, Clark Terry, Cootie Williams, and Ray Nance.

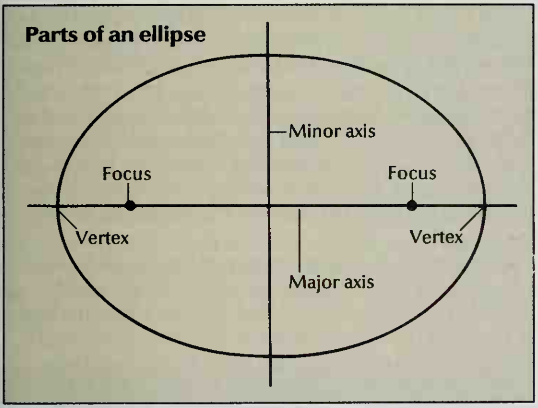
Beginning in the 1940's, Ellington composed longer works, such as *Black, Brown, and Beige* (1943). During the 1960's, Ellington wrote several film scores and began composing sacred music. *Music Is My Mistress* (1973) is Ellington's autobiography. Eddie Cook

See also African Americans (picture); Jazz (picture); Popular music (picture).

Elliot, Gilbert John Murray Kynynmond. See Minto, Earl of.

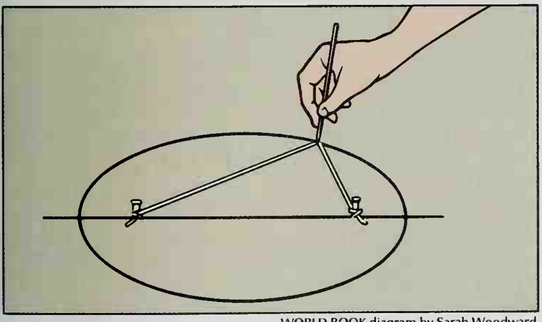
Ellipse, *ih LIHPS,* is a geometric figure with the shape of a flattened hoop. In geometric terms, an ellipse is one of the conic sections (see Cone).

An ellipse may be drawn with an *ellipsograph* (elliptic compass). But the simplest method to draw an ellipse is to fasten the ends of a string at two points, called the *foci* (see the drawings with this article). The string must be longer than the distance between the foci. Hold a pencil upright against the string so the string is stretched tight at all times. Draw half the ellipse; then lift the pencil and move the string to the other side of the pins to draw the second half. The diameter passing through the foci is called the *major axis.* The diameter running *perpendicular* (at right angles) to the major axis is the *minor axis.* To find the area of an ellipse, multiply half the length of the major axis by half that of the minor axis. Multiply the result by *pi,* which has an approximate value of 3.14159.



WORLD BOOK diagram by Sarah Woodward

An ellipse, in geometry, is an oval figure that resembles the shape of a flattened hoop.


WORLD BOOK diagram by Sarah Woodward

To draw an ellipse, pin the ends of a string at the two foci. The string must be longer than the distance between the two foci. An *ellipsograph* (elliptic compass) can also be used.

The ellipse was used by the German astronomer Johannes Kepler in the 1600's to describe the orbits of the planets of the solar system. Kepler discovered that each of the planets follows an elliptical path that has the sun as one of its foci. John K. Beem

Ellis, Havelock (1859-1939), was a British writer and psychologist. His writings did much to promote the scientific study of normal adult sexuality. Ellis's most important work is his seven-volume *Studies in the Psychology of Sex* (1897-1928). In it, he tried to be both scientific and aesthetic in his approach to psychology.

Henry Havelock Ellis was born in Croydon, now part of London. He studied medicine and worked for a time as a physician. In his *The World of Dreams* (1911), Ellis used a psychoanalytic method to study his own dreams (see Psychoanalysis). Ellis's works include *The Philosophy of Conflict and Other Essays* (1919) and *The Dance of Life* (1923). Phillip L. Rice

Ellis Island served as a United States reception center for immigrants for more than 60 years. The island is located in New York Harbor, less than $\frac{1}{2}$ mile (0.8 kilometer) north of Liberty Island, the home of the Statue of Liberty. Over 12 million people first entered the United States through Ellis Island. The island is named for Samuel Ellis, a merchant and farmer who owned it during the late 1700's. The United States government bought the island in 1808.

The government began using Ellis Island as an immigration station in 1892. About 35 buildings were constructed on the island. Newcomers were taken to the main building, an impressive two-story wooden structure. That building burned down in 1897, and was replaced by a three-story brick building. The immigrants were questioned by government officials and examined by doctors. Certain people were prohibited by federal law from immigrating to the United States. They included criminals, the insane, and people who had infectious diseases. But about 98 percent of those examined at Ellis Island were allowed into the country.

The island's large-scale use as an immigration station ended in 1924. The station closed completely in 1954. In 1965, the island became a national historic site, part of the existing Statue of Liberty National Monument. The site is managed and operated by the federal government's National Park Service.

The National Park Service began major repairs of the island's buildings in the 1980's. The island was reopened to the public in 1990. The main building was completely restored and is now the Ellis Island Immigration Museum. The museum's exhibits include old photographs, clothing, toys, and passports of immigrants. Visitors can listen to recordings of immigrants sharing their memories of Ellis Island. Several rooms, including the *Registry Room* or *Great Hall* (main reception area), now appear as they did between 1918 and 1924, the island's busiest years as an immigration station. The American Immi-

(©) Tony Savino, Sipa Press

Ellis Island's main building was the processing center for millions of immigrants as they entered the United States. Today, the building houses the Ellis Island Immigration Museum.

grant Wall of Honor, created in 1990, stands outside the museum. The names of almost 200,000 immigrants are engraved on this wall in honor of all immigrants.

Both the states of New York and New Jersey have long claimed official jurisdiction over Ellis Island. In 1834, the two states agreed to give New York official jurisdiction over the land while New Jersey got jurisdiction over the surrounding water and submerged land. At the time, the island covered only 3.3 acres (1.3 hectares). But through the years, landfill added 24.2 acres (9.8 hectares) to the total area. New Jersey sued New York to gain jurisdiction over the island. In 1998, a ruling by the Supreme Court of the United States gave New Jersey jurisdiction over all of the island except the original 3.3 acres, which New York kept. All buildings on Ellis Island are owned by the federal government, and the National Park Service continues to manage and operate the site.

Frank J. Coppa

Ellison, Harlan (1934-), is an American author best known for his science-fiction stories. He is also an important editor, essayist, and screenwriter. Ellison has gained recognition with his experiments in the form and techniques of science-fiction writing. He refuses to call himself a science-fiction writer, preferring to identify his work as "magic realism," a type of fiction that blends everyday reality with the supernatural.

Harlan Jay Ellison was born in Cleveland. He became a full-time writer in the mid-1950's and has written more than 1,100 short stories as well as many novels and essays. Ellison has written several of the most acclaimed short stories in modern science fiction, including " 'Repent Harlequin!' Said the Ticktock Man" (1965) and "I Have No Mouth, but I Must Scream" (1967). His essays have been published in such collections as *An Edge in My Voice* (1985) and *The Harlan Ellison Hornbook* (1990).

Ellison edited two influential collections of science-fiction stories, *Dangerous Visions* (1967) and *Again, Dangerous Visions* (1972). He also wrote screenplays for many television series, including "Star Trek" and "The Twilight Zone." He writes under many pen names, including Paul Merchant and Jay Solo. William A. Kumbier

Ellison, Ralph (1914-1994), an African American author, became famous for his novel *Invisible Man* (1952). The book reveals problems that blacks have experienced in their search for responsibility, dignity, and equality in the United States.

Invisible Man tells the story of a naive Southern black American who wants to take a proper place in society, but others interpret his role and place. In the South, they are defined by his grandfather, his parents, white community leaders, and the president of an all-black college. After being expelled from college, the youth goes to the North. There, he hears new definitions of his role from scientists, a black nationalist, and Communists. All these definitions fail him. However, while escaping from a riot in Harlem, he finds himself hiding in a hole in the ground. There, he discovers for himself that he must use his mind and heritage to develop his own definition of his role. He can return to society with a new awareness of his place in the world.

The novel is a complex work in which Ellison used symbols to explore several themes. One theme is that white Americans refuse to "see" blacks as a basic part of American society, and thus African Americans are "invisible." In another theme, Ellison suggested that all Americans must guard against loss of their humanity.

Ralph Waldo Ellison was born in Oklahoma City, Oklahoma. Several of his early short stories were collected in *Flying Home* (published in 1996, after his death). Ellison also published two collections of essays and other works, *Shadow and Act* (1964) and *Going to the Territory* (1986). An edited version of an unfinished novel was published as *Juneteenth* in 1999. Nellie Y. McKay

Ellsworth, Lincoln (1880-1951), an American civil engineer and polar explorer, became the first person to fly across both the Arctic Ocean and Antarctica. He was a mining engineer in Canada and Alaska and a field assistant with the United States Biological Survey. In 1925, he and Norwegian explorer Roald Amundsen made the first aerial crossing of the North Polar Basin, in a dirigible.

Ellsworth was coleader in 1926 of the Amundsen-Ellsworth-Nobile Transpolar Flight across the North Pole. He participated in the *Graf Zeppelin* dirigible flight to the Arctic in 1931. In 1935 and 1939, Ellsworth made flights across Antarctica. Each time, he claimed large new territories for the United States (see **Antarctica**).

Ellsworth was born in Chicago. He studied at Columbia and Yale universities. Ellsworth's books include *Search* (1932) and *Beyond Horizons* (1938). Antarctica's Ellsworth Land and Ellsworth Mountains are named after him. William Barr

Ellsworth, Oliver (1745-1807), was chief justice of the United States from 1796 to 1800. A noted lawyer, he served in the Continental Congress and was a delegate to the Constitutional Convention of 1787. Ellsworth was a Federalist U.S. senator from 1789 to 1796, and played the major role in drafting the important Judiciary Act of 1789. This act established the federal court structure. Much of the Judiciary Act's substance is still in effect today. He was born in Windsor, Connecticut.

Jerre S. Williams

Elm is a beautiful, large tree that is valued for its lumber and shade. Elms are common in North America, Europe, and some parts of Asia. Some North American elms have the shape of a vase, spreading out gradually from the bottom. In other elms, the limbs branch out from the

top of the trunk in the form of an umbrella. Many elms reach heights of 80 to 100 feet (24 to 30 meters). Some elms live more than 150 years.

Elms grow naturally along streams and the lower slopes of hillsides where the soil is well drained. However, they can grow in a variety of soils and terrains. In urban areas, elms are often planted along streets and in parks. They also are widely used in landscaping.

Elm wood is tough and hard, and usually light-brown in color. It does not split easily and is useful for making barrels, farm tools, fence posts, hockey sticks, furniture, and boats. It can also be used for fuel.

Kinds. There are about 20 species of elms. The *American elm,* also called the *white elm,* is the most widespread species in North America. This tree grows naturally throughout southeastern Canada and the eastern half of the United States. The small, greenish flowers of the American elm appear in the spring, before the leaves grow. The fruits, each with a little wing around it, fall to the ground as the leaves open. Most other elms produce their flowers in the spring, as well. Some species, including the *September elm* and the *cedar elm,* produce flowers and seeds in the fall.

Other important elms found in North America include the *rock elm,* the *slippery elm,* and the *English elm.* The rock elm gets its name from its extremely hard and tough wood. It is also called the *cork elm* because its bark is corky. The rock elm grows chiefly in the Great Lakes region. The slippery elm has a natural range almost as extensive as the American elm. Slippery elms have rough, hairy leaves and a gluey inner bark. The tall English elm is native to England and western Europe. The English elm has been widely planted in North America since colonial times.

Diseases. *Dutch elm disease* and *phloem necrosis* kill many elms each year. Dutch elm disease, so named because it was first observed in the Netherlands in 1919, was first noted in North America in 1930. Since then, it has spread through most of the range of the American elm, thus causing concern for the tree's future. The disease is caused by a fungus and spread primarily by native elm bark beetles and European elm bark beetles. It can also be transmitted from the roots of an infected tree to the roots of a nearby elm. Prompt removal of infected branches and trees is the most commonly used procedure for slowing the spread of the disease. See **Dutch elm disease**.

Species of elms that are resistant to Dutch elm disease have been planted in the United States as a substitute for the American elm. They include the *Siberian elm* and the *Chinese elm.* Several other potentially resistant elms have been identified, most of them hybrids of European and Asian species.

Phloem necrosis is caused by a microbe carried by insects called leaf hoppers. An infected tree cannot be recognized until its leaves begin to turn yellow and fall. By then it is too late for effective treatment.

Richard C. Schlesinger

Scientific classification. Elms belong to the elm family, Ulmaceae. The scientific name for the American elm is *Ulmus americana;* the slippery elm, *U. rubra;* the rock elm, *U. thomasii;* and the English elm, *U. procera.*

See also **Hackberry**.

William M. Harlow, Photo Researchers

An umbrella-shaped American elm has branches that spread out. These elms make good shade trees. Elm wood is used in making furniture, boats, and other products.

El Misti, *ehl MEES tee,* is a beautiful cone-shaped volcano in southern Peru. It lies in the Western Cordillera (see **Peru** [terrain map]). This mountain is 19,101 feet (5,822 meters) high. It is one of hundreds of volcanoes in the Cordillera. But none of the others surpasses it in beauty and symmetry. El Misti was of great religious significance to the ancient Inca. It figures in many Peruvian legends. The cone, snowcapped most of the year, furnishes water used to irrigate fields. Harvard University established an observatory near the summit of El Misti.

David J. Robinson

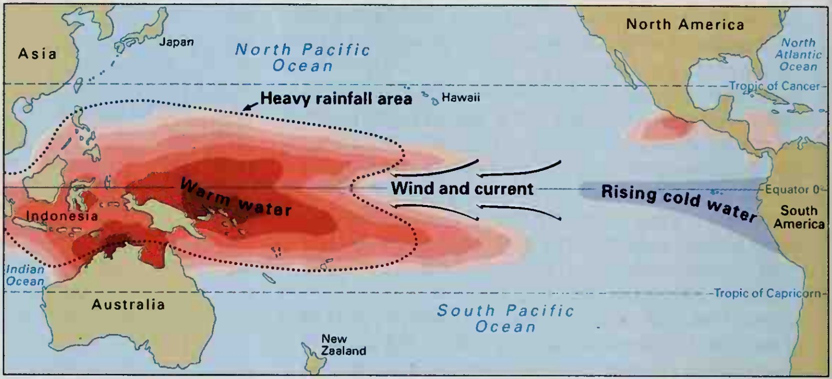
El Niño, *ehl NEEN yoh,* is a part of the interaction between the earth's atmosphere and the tropical waters of the Pacific Ocean. An El Niño occurs about every 2 to 7 years, and it can affect the climate throughout the world. In the United States, for example, the climate becomes wetter than normal in the south and drier than normal in the Pacific Northwest. Since the early 1980's, El Niños have become more frequent and more severe. A typical El Niño lasts approximately 18 months and is often followed by an opposite pattern that is called *La Niña.* The change back and forth between El Niño and conditions in which there is no El Niño is known as the *Southern Oscillation.*

In ocean science, the term *El Niño* originally referred to a current of warm water that flows southward along the coast of Ecuador and Peru every winter. The current was called El Niño because it usually occurs near Christmas. *El Niño* is Spanish for *the boy* and is used to refer to the Christ child. About every 2 to 7 years, the warm current is abnormally strong, lasts for an unusually long time, and is accompanied by changes in the winds and precipitation across the entire tropical Pacific region. For this reason, *El Niño* gradually came to refer to the entire interaction of the ocean and the atmosphere during the period of the stronger-than-normal current.

Climate without El Niño. When there is no El Niño, the warmest waters in the tropics are on the western side of the Pacific, near Indonesia. The air pressure over those waters is low. On the eastern side of the Pacific, near South America, the pressure of the overlying air is

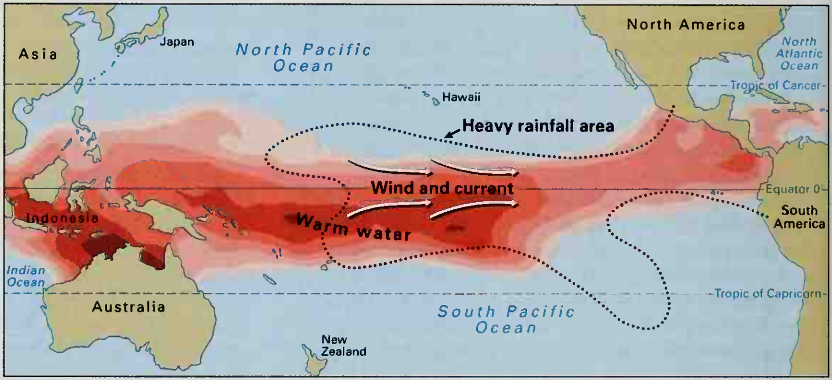
Climate without El Niño

When no El Niño is present, the warmest waters in the Pacific Ocean are in the west, and rainfall is heavy there. Near the equator, winds and ocean currents move from east to west. To replace water that flows away in the east, cold, nutrient-rich water rises to the surface, supporting a large population of fish.



Climate with El Niño

The east-to-west winds and currents weaken—or even reverse, as shown here—when an El Niño is present. As a result, the pattern of heavy rainfall shifts eastward. Because cold water no longer rises to the surface in the east, the fish population declines there.



WORLD BOOK maps
Maps based on data from the National Oceanic and Atmospheric Administration

high. Winds in the tropics blow from areas of high pressure to areas of low pressure. Over the tropical Pacific, therefore, the winds normally blow from east to west.

The winds of the tropical Pacific blow the surface waters from east to west. In the east, deeper cold water rises to the surface to replace the water that is blown away. The cold water is rich in minerals and other nutrients that feed tiny organisms drifting at and near the surface. The organisms, in turn, support a huge population of fish. As a result, the waters off Ecuador and Peru are one of the world's largest commercial fishing areas.

In the west, the warm ocean waters heat the air above them. The heated air is less dense than the cooler air surrounding it. The heated air therefore rises, producing clouds that provide rain to the western Pacific.

Climate with El Niño. During an El Niño, air pressure is higher than normal in the west and abnormally low in the east. The east-to-west winds over the tropical Pacific therefore weaken—or may even reverse. In either case, the waters off Ecuador and Peru become abnormally warm. Nutrient-rich cold water does not rise to the surface there, and so the fish population declines sharply.

Also during an El Niño, clouds and heavy rainfall occur mainly over the warmer water in the eastern Pacific. Consequently, the coast of South America becomes wetter than normal. To the west, by contrast, the climate in Indonesia and other nations of Southeast Asia is unusually dry. Droughts may even occur.

Climate with La Niña. *La Niña* is Spanish for *the girl.* In general, the climate associated with a La Niña is the opposite of that associated with an El Niño. During a La Niña, for example, the water in the western Pacific is even warmer than it is when there is merely no El Niño.

Rajul E. Pandya

See also **Climate** (Changes in ocean circulation).

Elodea, *uh LOH dee uh,* is a plant that grows submerged in water. It is sometimes called *waterweed.* Its branching stems are densely covered with leaves that grow even more crowded toward the tip. These plants are commonly used in aquariums to keep the oxygen balance in the water. They are also used to demonstrate that oxygen is a product of photosynthesis (see **Photosynthesis**). When elodea is exposed to light, oxygen bubbles appear around the leaves. David A. Francko

Scientific classification. Elodea belongs to the frogbit family, Hydrocharitaceae. Its scientific name is *Elodea canadensis.*

Elohim, *eh loh HEEM* or *eh LOH hihm,* is a Hebrew word that means *gods, a god,* or *God,* depending on the context in which it is used. In most cases, it means *God.* In the Old Testament, *Elohim* is one of the two most commonly used names for God. The other is *Yahweh.* The word *Elohim* appears in the first sentence of the Bible: "In the beginning God (Elohim) created heaven and earth" (Genesis 1:1). H. Darrell Lance

El Paso, *ehl PAS oh* (pop. 563,662, met. area pop. 679,622), is a city in Texas that lies along the border between the United States and Mexico. It serves as a major gateway for travel and commerce between the two countries. It is also an important distributing and manufacturing center of the southwestern United States. El Paso sprawls along the north bank of the Rio Grande at the far western tip of Texas. It lies in a desert in a pass between the Franklin Mountains to the north and the Sierra Madre of Mexico to the south. Part of the city ex-

tends into the Franklins. For location, see Texas (political map). El Paso's sister city of Juárez, Mexico, lies across the Rio Grande.

In 1598, the Spanish explorer Juan de Oñate arrived at what is now El Paso. He named the area *El Paso del Norte* (the pass of the north). The pass became a major stop on *El Camino Real* (the Royal Highway) between Mexico City and the Spanish colonies of New Mexico.

The city. El Paso, the seat of El Paso County, covers 247 square miles (640 square kilometers). The El Paso metropolitan area covers 1,014 square miles (2,626 square kilometers). San Jacinto Plaza, a bustling symbol of the city's Spanish and Mexican heritage, is in the heart of downtown El Paso. The downtown also includes the El Paso Convention and Performing Arts Center and the 21-story State National Bank of El Paso, the city's tallest building. The University of Texas at El Paso, known for its Tibetan-style architecture, is northwest of downtown. Fort Bliss, which extends from northeast El Paso into New Mexico, houses the United States Army Air Defense Artillery Center.

More than 75 percent of the people of El Paso—called El Pasoans—have Hispanic ancestry, and both English and Spanish are spoken in much of the city. Other groups include African Americans and people of English, German, and Irish descent. Indians related to the Pueblo Indians of New Mexico live on the Tigua Indian Reservation, which is in the city.

Economy. About 600 manufacturing companies operate in El Paso County. The production of cotton clothing ranks as the major industry. Other industries include food processing, oil refining, copper smelting and refining, and the manufacture of leather goods—especially Western boots. Fort Bliss and other nearby military bases provide many civilian jobs. Farming, especially the growing of cotton and chiles, and cattle raising are important in the surrounding area. These activities employ thousands of El Pasoans seasonally.

Since the 1970's, the economies of El Paso and Juárez have developed a major border industry known as the *maquiladora* or *twin plants*. Assembly plants in Juárez manufacture such products as electronic equipment, automobile parts, and clothing from materials produced in the United States. Many of these materials are gathered in El Paso and transported from the city into Mexico. El Paso also helps transport the finished products from Mexico to the United States.

Railroads and truck lines provide freight service to El Paso. Amtrak passenger trains stop in the city, and several airlines serve El Paso International Airport. Major highways connect the city with other parts of the United States and with Mexico. Three bridges span the Rio Grande between El Paso and Juárez. El Paso has one daily newspaper, the *El Paso Times*.

Education and cultural life. El Paso's public school system includes about 90 elementary schools and 20 high schools. The city also has over 20 parochial and other private schools. It is the home of a campus of the University of Texas. El Paso Community College has campuses around the city. The El Paso Public Library operates a main library and a number of branches.

El Paso has a symphony orchestra, the Ballet of the Americas, and a number of theater companies. In addition, the city operates the El Paso Museum of Art, the El Paso Museum of History, and other museums. Fort Bliss has several museums of military history.

Many festivals are held in the city. One of the largest is the Sun Carnival, which includes a Thanksgiving Day parade in November and the Sun Bowl football game in December. Major Mexican holidays are widely celebrated in El Paso. About 100 city parks cover a total of 930 acres (380 hectares) in El Paso. Ascarate Park, the largest, spreads across 353 acres (143 hectares) and includes a lake for fishing and boating. The city zoo is in Washington Park.

Government. El Paso has a mayor-council form of government. Voters elect a mayor and eight council members, all to two-year terms. The city government gets most of its revenue from property taxes.

History. Manso and Suma Indians lived in what is now the El Paso area when Europeans first arrived there. Juan de Oñate claimed the area for Spain in 1598 and named it El Paso del Norte. Spanish priests set up their first mission in the area in 1659, in what is now Juárez. In 1680, Pueblo Indians drove Spanish settlers out of northern New Mexico. The settlers, along with a group of Pueblos who later became the Tiguas, fled to the Rio Grande. There, they founded Ysleta, now part of El Paso; and Socorro, now a suburb. Ysleta and Socorro were Texas's first towns. In 1682, the first two missions in Texas were built near the present site of El Paso.

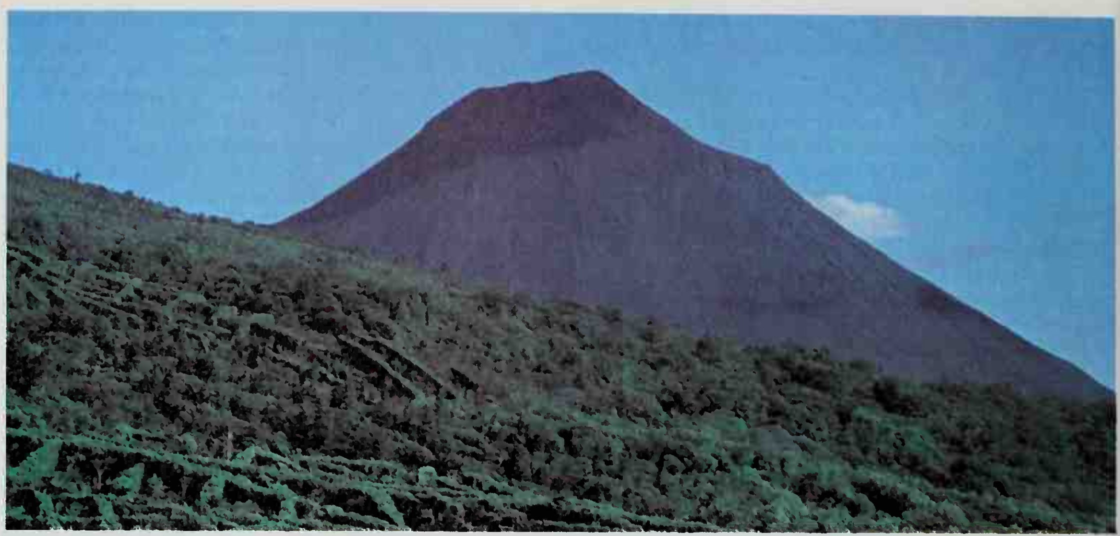
El Paso del Norte came under Mexican control in the early 1820's after Mexico gained independence from Spain. In 1848, following the Mexican War, the Treaty of Guadalupe Hidalgo established the Rio Grande as part of the boundary between the United States and Mexico. The section of El Paso del Norte north of the river became the U.S. community of El Paso. The southern part, Mexican territory, was later renamed Juárez.

The U.S. Army opened Fort Bliss in 1854. During the American Civil War (1861-1865), the fort surrendered to the Confederacy, and a Confederate force marched north from there to invade New Mexico. After being defeated at Glorieta Pass in New Mexico in 1862, the Confederates abandoned Fort Bliss and retreated to San Antonio.

El Paso was incorporated as a city in 1873. It had 173 residents. A railroad arrived in the city in 1881 and helped cause a land boom. By 1890, 10,338 people lived in El Paso. The city had a reputation as a rough and rowdy border town where gunfights were common.

The population of El Paso continued to grow during the 1900's. Employment opportunities with the railroad and in mining and ranching drew many people to the city. By 1910, the population had almost reached 40,000. In 1916, Elephant Butte Dam was completed across the Rio Grande about 132 miles (212 kilometers) north of El Paso. The reservoir created by the dam supplies water to parts of Texas, New Mexico, and Mexico. It helped increase agricultural activity around El Paso, and the population of the city reached 102,421 by 1930. During the 1950's, manufacturing expanded rapidly and the population more than doubled from 130,485 in 1950 to 276,687 in 1960. By 2000, the population had risen to 563,662.

Today, El Paso, a desert city, is searching for new sources of water to meet the needs of its growing population. Air pollution from the industrial growth in El Paso and Juárez is also a problem. Robert Locke



Bruce Coleman Inc.

A coffee plantation covers the rolling countryside below the volcano Izalco in central El Salvador. Coffee, the nation's leading crop, thrives in the rich volcanic soil and mild climate.

El Salvador

El Salvador, *ehl SAL vuh DAWR,* is the smallest Central American country in area. However, it ranks as the third largest country in population in Central America. Only Guatemala and Honduras have more people than El Salvador.

El Salvador is a tropical land of rugged mountains, cone-shaped volcanoes, green valleys, and scenic lakes. The Pacific Ocean lies to its south, Guatemala to its northwest, and Honduras to its northeast.

El Salvador ranks as the most densely populated nation on the mainland of the Americas. It has about 10 times as many people per square mile as the United States. Ownership of scarce fertile land—El Salvador's main resource—has been a cause of turmoil and conflict in the country.

As the supply of land became exhausted, many Salvadorans began to move from rural to urban areas, beginning in the 1940's. About 300,000 other Salvadorans who wanted land settled illegally in sparsely populated areas of neighboring Honduras, where their presence sparked a brief war in 1969.

In 1979, civil war broke out between leftist guerrillas and the Salvadoran government. During the war, about 1 million Salvadorans, one-fifth of the population, sought refuge in neighboring Central American countries and the United States. Hundreds of thousands more sought safety by moving to El Salvador's cities. The war ended in 1992.

The majority of El Salvador's people are of mixed Indian and Spanish ancestry. Most Salvadorans live in central El Salvador, the agricultural and industrial heartland. San Salvador, the capital and largest city, lies in this region. More than half the people are farmers. Coffee is El Salvador's leading crop.

In 1525, Spanish soldiers led by Pedro de Alvarado conquered what is now El Salvador for Spain. Alvarado directed the founding of San Salvador that year. He named it for the Roman Catholic feast of *San Salvador del Mundo* (Holy Savior of the World), for which the entire country was later named.

Nathan A. Haverstock, the contributor of this article, is an Affiliate Scholar at Oberlin College, and author of more than a dozen books on Latin America.

Government

Under El Salvador's present Constitution, adopted in 1983, the country is a representative democracy with executive, legislative, and judicial branches of government. The president has executive power and is chosen

Facts in brief

Capital: San Salvador.
Official language: Spanish.
Official name: República de El Salvador (Republic of El Salvador).
Area: 8,124 mi^2 (21,041 km^2). *Greatest distances*—north-south, 88 mi (142 km); east-west, 163 mi (262 km). *Coastline*—189 mi (304 km).
Elevation: *Highest*—Monte Cristo, 7,933 ft (2,418 m) above sea level. *Lowest*—sea level along the coast.
Population: *Estimated 2002 population*—6,507,000; density, 801 per mi^2 (309 per km^2); distribution, 58 percent urban, 42 percent rural. *1992 census*—5,118,599.
Chief products: *Agriculture*—beans, coffee, corn, cotton, rice, sugar cane. *Manufacturing*—chemicals, cigarettes, processed foods and beverages, leather goods, textiles.
Money: *Basic units*—colón and United States dollar.

Yoram Kahana from Peter Arnold

Outdoor markets are set up on weekends in many Salvadoran towns. Shoppers can buy produce and handwoven articles.

by the people for a five-year term. The president cannot serve two consecutive terms. The legislative branch consists of the single-chamber Legislative Assembly. The Assembly has 84 members who are elected by popular vote to three-year terms. A supreme court has judicial authority.

For administrative purposes, El Salvador is divided into 14 departments, which are subdivided into 262 *municipios* (townships). Each department has a governor appointed by the president. A council governs each municipio. The people elect their council members to three-year terms.

The country has six major political parties: the extremely conservative Nationalist Republican Alliance (ARENA), the conservative National Conciliation Party, the evangelical Unity Movement, the moderate Christian Democratic Party, the leftist Farabundo Martí National Liberation Front (FMLN), and the leftist Democratic Convergence—a group formed by former rebels after the civil war.

About 30,000 people serve in the armed forces. Each Salvadoran man between ages 18 and 30 must serve at least two years in the military, unless he is an only child.

People

Ancestry. More than 90 percent of all Salvadorans are *mestizos* (people of mixed Indian and white descent). Nearly 5 percent are of unmixed white ancestry, and most of the rest are Indians.

The pure-blooded Indians of El Salvador are mostly descended from the Pipil Indians, the dominant tribe in the area when the Spanish conquerors arrived. The Indians live mainly in the southwestern highlands near the Guatemalan border. A few Indians still speak the ancient Nahuatl language of the Pipils and follow the traditional ways of life of the tribe.

Religion. Approximately 80 percent of Salvadorans, including most Indians, are members of the Roman Catholic Church. The Roman Catholic Church plays an active role in the ongoing struggle for social justice in El Salvador. Small Protestant sects in the country won many converts during the 1980's.

Housing. In rural areas, some farmers own adobe houses with a dirt floor and thatched roof. Poorer country people live in *wattle huts,* which have walls made of interwoven branches covered with mud. The wealthy owners of coffee plantations live in spacious homes on the scenic hillsides of their estates.

In the cities, many poor families rent one-room apartments in crowded, decaying buildings. Middle-class city residents live in *row houses* (houses of similar design that share a common wall) or in comfortable apartments. The rich live in the suburbs and own luxurious, modern homes surrounded by landscaped gardens.

Food. Most Salvadorans eat mainly beans, bread, corn, and rice. When they can afford them, they also eat dairy products and meat. Salvadorans have bread and coffee for breakfast and eat their main meal at midday. In the late afternoon, many people snack on *pupusas* (corn-meal cakes stuffed with chopped meat, beans, and spices). This Salvadoran specialty is sold at many roadside stands.

Education. A majority of El Salvador's adults can read and write. For the country's literacy rate, see **Literacy** (table: Literacy rates). El Salvador's system of public education is inadequate. In poor rural areas, more than half of the children of elementary school age have no school.

Education has improved in middle- and upper-class

El Salvador's flag was adopted in 1912. The blue stripes represent unity. The white one symbolizes peace.

The coat of arms has a triangle that represents equality. The flags stand for the Central American nations.

WORLD BOOK map

El Salvador is a Central American country that lies along the North Pacific Ocean. It borders Guatemala and Honduras.

Cities

Acajutla	18,008	C	1
Aguilares	16,984	B	2
Ahuachapán	26,840	B	1
Antiguo Cuscatlán*	26,722	C	3
Apopa	88,827	B	2
Armenia	11,864	C	2
Atiquizaya	7,498	B	1
Ayutuxtepeque*	20,137	C	2
Berlín*	8,951	C	4
Chalatenango	15,306	B	3
Chalchuapa	25,545	B	1
Chinameca	6,842	C	4
Chirilagua	5,059	D	4
Ciudad Arce	7,989	B	2
Coatepeque	4,568	B	2
Cojutepeque	38,230	C	3
Concepción de Ataco*	6,169	B	1
Cuscatancingo*	35,139	C	2
Delgado	56,701	C	2
El Congo*	7,047	B	2
El Tránsito	7,506	C	4
Guatajiagua*	†5,301	C	4
Ilobasco	18,092	B	3
Ilopango*	79,069	C	2
Intipuca	†5,164	D	5
Izalco	15,187	B	1
Jayaque*	3,492	C	2
Jiquilisco	7,223	D	4
Juayúa	7,860	B	1
Jucuapa	8,388	C	4
La Libertad	13,338	C	2
La Unión	21,091	D	5
Mejicanos	131,972	C	2
Metapán	15,148	A	2
Nueva Concepción	7,903	B	2
Nueva San Salvador	98,392	C	2
Olocuilta	5,004	C	3
Opico	5,640	B	2
Puerto El Triunfo	7,833	C	4
Quezaltepeque	22,859	B	2
San Alejo	†5,348	C	5
San Francisco Gotera	12,659	C	5
San Jorge*	†5,485	C	4
San Juan Nonualco	†5,011	C	3
San Marcos	43,254	C	2
San Martín	31,173	C	3
San Miguel	127,696	C	4
San Rafael*	7,384	C	4
San Salvador	415,346	C	2
San Sebastián	5,802	C	3
San Vicente	29,455	C	3
Santa Ana	139,389	B	2
Santa Elena	†5,881	C	4
Santa Rosa de Lima	10,480	C	5
Santiago de María	11,894	C	4
Santiago Nonualco	7,509	C	3
Santo Tomás*	11,548	C	3
Sensuntepeque	16,021	B	4
Sonsonate	46,830	C	1
Soyapango*	261,122	C	3
Suchitoto	†6,857	B	3
Tonacatepeque*	†5,602	B	3
Usulután	40,971	D	4
Zacatecoluca	31,424	C	3

*Does not appear on map; key shows general location.
†1984 official estimates.
Source: 1992 census

neighborhoods of cities. Students who complete nine years of elementary school may go to public secondary schools for three more years and then attend a university. El Salvador has three universities and several technical schools that prepare young people for careers in agriculture, communications, engineering, and various other fields.

Recreation. Salvadorans love to spend their leisure time outdoors. Many people play soccer, the national sport, in neighborhood fields. Many families spend their weekends at resorts near lakes or on the beaches along the Pacific. Los Chorros is a popular national park located near Nueva San Salvador. The park has four public swimming pools that are surrounded by tropical gardens and waterfalls. El Salvador's most colorful religious festival celebrates the Feast of the Holy Savior of the World. The festival lasts from July 24 to August 6. It includes carnival rides, fireworks, folk dancing, and processions.

Social problems. El Salvador faces the problem of rebuilding its society following years of bitter civil war. During the war, members of the same family sometimes fought on opposite sides. The war greatly increased poverty in the country. It resulted in displacement of people, resulting in increased slums. The country faces the problem of caring for war victims, including many orphans. The war damaged the structure of family life in El Salvador. Many wage earners left their families behind to search for jobs. It is estimated that in El Salvador only about half of the men and women who live together are married.

The land

El Salvador consists of three main land regions. These regions are, from south to north, (1) the Coastal Lowlands, (2) the Central Region, and (3) the Interior Highlands.

The Coastal Lowlands consist of a narrow, fertile plain along the Pacific shore. The lowlands extend 10 to 20 miles (16 to 32 kilometers) inland. Large sections of the land have been developed for farming. Many factories and a fishing industry are located near Acajutla, the leading port.

The Central Region forms the heartland of El Salvador. About three-fourths of the nation's people live there, many of them in such large cities as San Salvador and Santa Ana. The region also has most of the country's industry and fertile farmland. The Coastal Range, a band of rugged mountains and high, inactive volcanoes, forms the region's southern border. On the range's

Bruce Coleman Inc.

Rush-hour traffic inches its way along a busy street in San Salvador, El Salvador's capital. Each year, thousands of rural Salvadorans move to the already overcrowded city to seek work.

© Carl Frank, Photo Researchers, Inc.

A Salvadoran farmhouse called a *wattle hut* has walls made of interwoven branches covered with mud. Many poor farmers of El Salvador live in wattle huts.

lower slopes, coffee plantations and cattle ranches sprawl among forests of oak and pine trees. A broad plateau of gently rolling land lies north of the Coastal Range. The plateau's volcanic soil and green pastures make it El Salvador's chief agricultural region.

The Interior Highlands occupy northern El Salvador and make up the most thinly populated region of the country. The Sierra Madre—a low mountain range of hardened lava, rocks, and volcanic ash—covers most of the highlands. El Salvador's largest river, the Lempa, rises in the Sierra Madre and flows 200 miles (320 kilometers) to the Pacific. Only a few small farms and ranches are located in the area.

Climate

El Salvador has a tropical climate that varies slightly from area to area because of differences in altitude. Average year-round temperatures range from 80 °F (27 °C) in Acajutla along the coast to 73 °F (23 °C) in Santa Ana in the mountains.

Showers fall every afternoon in the rainy season, which lasts from May to October. Yearly rainfall ranges from 85 inches (216 centimeters) along the coast to less than 60 inches (150 centimeters) in the northwest.

WORLD BOOK map

El Salvador has three main land regions—the Central Region, where most of the people live; the humid Coastal Lowlands; and the cool Interior Highlands.

Economy

El Salvador's chief natural resource is its fertile volcanic soil. The country also has small deposits of gold and silver. Most of its electric power comes from hydroelectric plants on the Lempa River. Off the Pacific Coast, fishing crews catch shrimp and lobsters.

The nation's economy depends mainly on agriculture. Cropland and pastures cover three-fourths of the country, and over half of all workers are farmers or ranchers. The ranchers raise beef and dairy cattle. Many of the farmers own small farms. They cultivate beans, corn, rice, and other crops for their families and for local markets. Other farmers work on large commercial plantations called *fincas,* which raise coffee, cotton, and sugar cane. Coffee, El Salvador's leading crop, is raised throughout the country. But it grows best at the high elevations near Santa Ana. Cotton and sugar cane thrive in the warm, humid lowlands along the coast.

The federal government has encouraged the creation of new industries to lessen the nation's dependence on agriculture. Its efforts have helped expand industrialization, but manufacturing still accounts for only a small percentage of El Salvador's national income. The leading industries produce chemicals, cigarettes, foods and beverages, leather goods, and textiles.

El Salvador's prosperity depends largely on the export of coffee, cotton, sugar, and textiles. Coffee accounts for almost half the country's export earnings. El Salvador's chief imports include chemicals, food, machinery, and petroleum. Germany, Guatemala, and the United States are El Salvador's main trading partners. El Salvador belongs to the Central American Common Market, an economic union that was formed to stimulate trade among its members.

El Salvador has a good network of highways. The Pan American Highway spans the country from east to west. Less than 2 per cent of all Salvadorans own an automobile. Most people travel by bus. A majority of Salvadoran families own one or more radios. The country has an

average of about 1 television set for every 17 people. There are six daily newspapers.

History

Indians were the first people to live in what is now El Salvador. Nahua Indians arrived from Mexico as early as 3000 B.C. Later, other Indians settled in the region. The ruins of huge limestone pyramids built by Maya Indians between A.D. 100 and 1000 still stand in western El Salvador. The Pipil tribe seized control of the lands west of the Lempa River during the 1000's. The Pipil built cities, raised crops, and were skillful weavers.

Colonial period. In 1524, Spanish soldiers led by Pedro de Alvarado invaded El Salvador. After a fierce struggle, the Spaniards defeated the Pipil and other tribes the next year. El Salvador then remained a Spanish colony for almost 300 years. The colony had little mineral wealth. As a result, it attracted fewer settlers than did Spain's other colonies in the New World. Most of the colonists in El Salvador farmed the land and raised cattle.

Independence. In 1821, El Salvador and Spain's other Central American colonies broke away from Spanish rule. All but Panama joined together in a *federation* (union) called the United Provinces of Central America in 1823. José Matías Delgado, a Salvadoran Catholic priest, led El Salvador's revolt against Spain and headed the convention that drafted the federation's constitution. The union began to collapse in 1838. El Salvador withdrew in 1840. In 1841, El Salvador formally declared its independence from the federation.

Political violence shook El Salvador during the rest of the 1800's. Five of the country's presidents were overthrown by force, and two others were executed. The strong dictators of neighboring countries, including Rafael Carrera of Guatemala, controlled several weak Salvadoran presidents.

The 1900's. After 1900, the government became more stable. Most presidents were wealthy landowners. In addition, the country began to prosper with the cultivation of coffee and other farm products for export. Rich Salvadorans who made up only a small percentage of the population owned most of the choice farmland. Many rural people had poor farmland or no land.

In 1931, General Maximiliano Hernández Martínez seized the government and ruled as a dictator for 12 years. He built many public schools, expanded social service programs, and supported labor reform. A revolution led by soldiers and university students deposed him in 1944. In the 1940's, large numbers of landless Salvadoran farmers began to settle on the sparsely populated countryside across the border in Honduras.

From the 1950's to the 1970's, military governments ruled El Salvador. A series of army officers became president, interrupted by two military *juntas* (councils) that seized power in the early 1960's.

Recent developments. In 1969, Honduran land reform laws forced many Salvadorans living in Honduras to give up their land. Tensions created by these laws and by a long-standing border dispute between El Salvador and Honduras erupted into a four-day war. The Organization of American States arranged a cease-fire. In 1992, El Salvador and Honduras ended their border dispute. Colonel Arturo Armando Molina became president in 1972. General Carlos Humberto Romero succeeded Molina in 1977.

In the late 1970's, widespread protests broke out in El Salvador. The protesters demanded that the government provide land and jobs for the poor. Some members of the Roman Catholic clergy supported the protesters. Some protesters kidnapped business and political leaders to raise money through ransom for their cause.

In 1979, army officers removed Romero from office and replaced him with a junta consisting of two army officers and three civilians. Also in 1979, civil war broke out between government troops and rebel leftist guerrilla forces belonging to the Farabundo Martí National Liberation Front (FMLN). The assassination of Archbishop Oscar Arnulfo Romero in March 1980 led to an escalation of the fighting and touched off widespread rioting. Archbishop Romero had been an outspoken critic of the government.

With the level of violence in El Salvador increasing, the junta appointed José Napoleón Duarte president in December 1980. Duarte, a civilian and a member of the Christian Democratic Party, immediately began a number of reforms, including a major program to distribute land to poor people. But violence continued.

During the administration of U.S. President Ronald Reagan (1981-1989), the U.S. government provided large-scale financial and military assistance to El Salvador's government. The United States also sent military advisers to help the government.

In 1983, an elected Constituent Assembly completed a new Constitution that provided for the restoration of democracy in El Salvador. In 1984, the voters elected Duarte president.

In 1986, an earthquake struck San Salvador. It caused about 1,020 deaths and widespread property damage, and left many people homeless.

In 1989, the voters elected Alfredo Cristiani of the right wing ARENA party president. Also in 1989, FMLN forces staged an offensive across El Salvador. The assault resulted in the worst fighting of the civil war up to that time. Civilian casualties were heavy, especially in San Salvador and other cities. Finally, on Jan. 16, 1992, the government and the FMLN signed a peace agreement. A cease-fire went into effect on February 1. The war officially ended on Dec. 15, 1992, with the disbanding of FMLN forces and a reduction in the armed forces of El Salvador. About 75,000 people died in the war.

Since 1989, the voters of El Salvador have elected a new president every five years. Francisco Flores Pérez was elected president in 1999.

Earthquakes struck El Salvador in January and February 2001. They killed about 1,200 people and left more than 1 million homeless. Nathan A. Haverstock

Related articles in *World Book* include:

Delgado, José Matías
Maya
Romero, Oscar Arnulfo
San Salvador

Outline

IV. Climate
V. Economy
VI. History

Questions

What is El Salvador's leading crop?
What percentage of El Salvador's adults can read and write?
What are El Salvador's three main regions?
Who are the *mestizos*?
What is the national sport of El Salvador?
What are *pupusas*?
How did El Salvador get its name?
What is El Salvador's chief natural resource?
Who was Archbishop Oscar Arnulfo Romero?
Who were the two sides in El Salvador's civil war?

Elton, Charles Sutherland (1900-1991), was an English biologist. He was known as a pioneer in establishing the science of *ecology,* which deals with the relation of living things to their environment and to one another.

Elton recognized that animal species and populations fit together in their environment to form communities. He recognized the concept of *ecological niche*—the idea that each species has a unique function and place within the environment (see **Ecology** [The role of a species]). Elton also pointed out that a large number of plants are needed to supply food for a smaller number of plant-eating animals. Such animals, in turn, provide food for an even smaller number of meat-eating creatures. Elton called this natural system of food relationships a *pyramid of numbers.*

Elton was born in Manchester and graduated from Oxford University in 1922. He taught animal ecology at Oxford from 1932 until he retired in 1967. Elton wrote *Animal Ecology* (1927) and *The Pattern of Animal Communities* (1966). G. J. Kenagy

El Toro Marine Corps Air Station, California, was the headquarters of the United States Marine Corps Air Bases Command, Western Area. It was closed in 1999. The base was located 8 miles (13 kilometers) southeast of Santa Ana. It began operation in 1943. The air base received its name from the nearby community of El Toro.

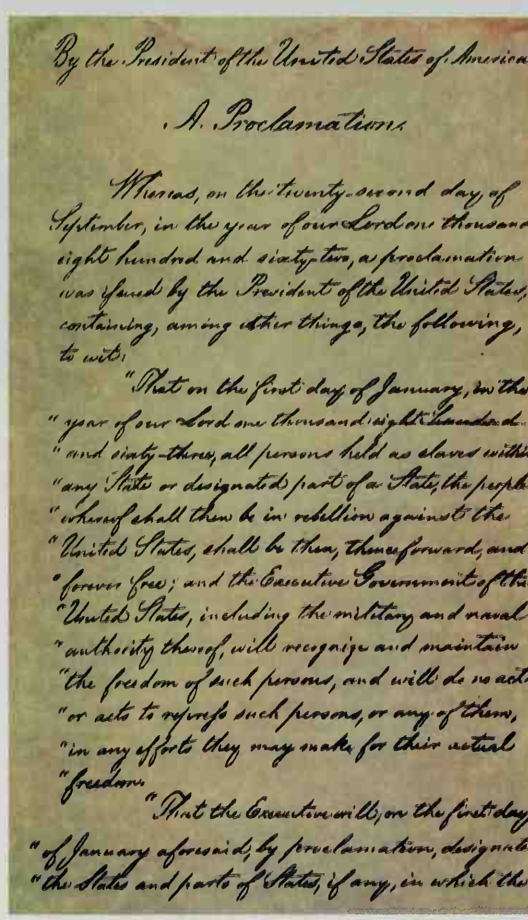
Critically reviewed by the United States Marine Corps

Elysium, *ih LIHZH uhm* or *ih LIHZ ee uhm,* in Greek and Roman mythology, was the place to which the souls of heroes were sent after death as a reward for their virtuous lives. Elysium was a land of sunshine and cool breezes, and of beautiful flowers growing in fragrant meadows. The souls lived there in perfect joy, enjoying athletics and dances, and singing hymns to the gods. Elysium was sometimes called the Elysian Fields or the Islands of the Blessed. Justin M. Glenn

Elzevir, *EHL zuh VEER,* **Louis** (1546?-1617), was the first of what became a famous Dutch family of publishers, printers, and sellers of books. The family was in the book business from about 1583 to 1712. The family name is also spelled *Elsevier* or *Elzevier.* The Elzevirs became known for their elegant, pocket-sized editions of Latin classics and French literature. These books, known as *Elzevirs,* were sold throughout Europe. A large number of Elzevir books were printed in type faces that were created by Cristoffel van Dijck, a well-known Dutch designer.

Elzevir began his career as a binder and bookseller and eventually also became a publisher at the University of Leiden. After his death, his sons and their families established branches of his business in Amsterdam, The Hague, and Utrecht. Peter M. VanWingen

Emancipation Proclamation was a historic document that led to the end of slavery in the United States. President Abraham Lincoln issued the proclamation on Jan. 1, 1863, during the Civil War. It declared freedom



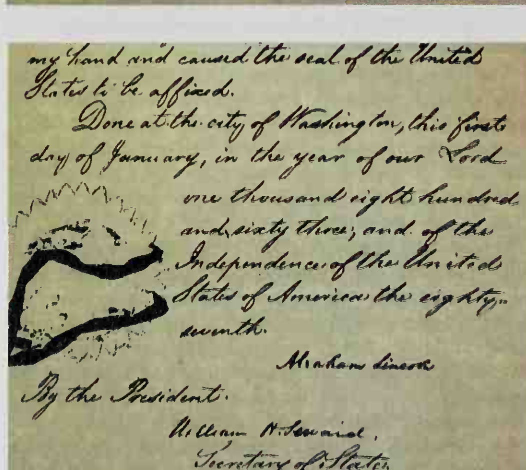
By the President of the United States of America:

A Proclamation.

Whereas, on the twenty-second day of September, in the year of our Lord one thousand eight hundred and sixty-two, a proclamation was issued by the President of the United States, containing, among other things, the following, to wit:

"That on the first day of January, in the year of our Lord one thousand eight hundred and sixty-three, all persons held as slaves within any State or designated part of a State, the people whereof shall then be in rebellion against the United States, shall be then, thenceforward, and forever free; and the Executive Government of the United States, including the military and naval authority thereof, will recognize and maintain the freedom of such persons, and will do no act or acts to repress such persons, or any of them, in any efforts they may make for their actual freedom.

"That the Executive will, on the first day of January aforesaid, by proclamation, designate the States and parts of States, if any, in which the



my hand and caused the seal of the United States to be affixed.

Done at the city of Washington, this first day of January, in the year of our Lord one thousand eight hundred and sixty three, and of the Independence of the United States of America the eighty-seventh.

Abraham Lincoln

By the President:

William H. Seward, Secretary of State.

Granger Collection

Emancipation Proclamation was issued on Jan. 1, 1863. The first and fifth pages of the famous document are shown here.

Lincoln read the preliminary Emancipation Proclamation to his Cabinet on Sept. 22, 1862. This painting by Francis Carpenter shows, *from left to right,* Edwin M. Stanton, Salmon P. Chase, Lincoln, Gideon Welles, Caleb B. Smith, William H. Seward, Montgomery Blair, and Edward Bates.

Oil painting by Francis Bicknell Carpenter in the Senate wing, Capitol, Washington, D.C. (U.S. Capitol Historical Society; photo by George F. Mobley, National Geographic Society)

for slaves in all areas of the Confederacy that were still in rebellion against the Union. The proclamation also provided for the use of blacks in the Union Army and Navy. As a result, it greatly influenced the North's victory in the war.

Events leading to the proclamation

Early views on emancipation. The 11 states of the Confederacy *seceded* (withdrew) from the Union in 1860 and 1861. They seceded primarily because they feared Lincoln would restrict their right to do as they chose about the question of black slavery. The North entered the Civil War only to reunite the nation, not to end slavery.

During the first half of the war, abolitionists and some Union military leaders urged Lincoln to issue a proclamation freeing the slaves. They argued that such a policy would help the North because slaves were contributing greatly to the Confederate war effort. By doing most of the South's farming and factory work, slaves made whites available for the Confederate Army.

Lincoln agreed with the abolitionists' view of slavery. He once declared that "if slavery is not wrong, nothing is wrong." But early in the war, Lincoln believed that if he freed the slaves, he would divide the North. Lincoln feared that four slave-owning border states—Delaware, Kentucky, Maryland, and Missouri—would secede if he adopted such a policy.

Lincoln's change of policy. In July 1862, with the war going badly for the North, Congress passed a law freeing all Confederate slaves who came into Union lines. At about that same time, Lincoln decided to change his stand on slavery. But he waited for a Union military victory, so that his decision would not appear to be a desperate act.

On Sept. 22, 1862, five days after Union forces won the Battle of Antietam, Lincoln issued a preliminary proclamation. It stated that if the rebelling states did not return to the Union by Jan. 1, 1863, he would declare their slaves to be "forever free." The South rejected Lincoln's policy, and so he issued the Emancipation Proclamation on Jan. 1, 1863. Lincoln took this action as commander in chief of the Army and Navy of the United States. He called it "a fit and necessary war measure."

Effects of the proclamation

The Emancipation Proclamation did not actually free a single slave, because it affected only areas under Confederate control. It excluded slaves in the border states and in such Southern areas under Union control as Tennessee and parts of Louisiana and Virginia. But it did lead to the 13th Amendment to the Constitution. This amendment, which became law on Dec. 18, 1865, ended slavery in all parts of the United States.

As the abolitionists had predicted, the Emancipation Proclamation strengthened the North's war effort and weakened the South's. By the end of the war, more than 500,000 slaves had fled to freedom behind Northern lines. Many of them joined the Union Army or Navy or worked for the armed forces as laborers. By allowing blacks to serve in the Army and Navy, the Emancipation Proclamation helped solve the North's problem of declining enlistments. About 200,000 black soldiers and sailors, many of them former slaves, served in the armed forces. They helped the North win the war.

The Emancipation Proclamation also hurt the South by discouraging the United Kingdom and France from entering the war. Both of those nations depended on the South to supply them with cotton, and the Confederacy hoped that they would fight on its side. But the proclamation made the war a fight against slavery. Most British and French citizens opposed slavery, and so they gave their support to the Union. James M. McPherson

See also Adams, John Quincy (The Gag Rules); Civil War; Constitution of the United States (Amendment 13).

Additional resources

January, Brendan. *The Emancipation Proclamation.* Children's Pr., 1997. Younger readers.
Klingaman, William K. *Abraham Lincoln and the Road to Emancipation, 1861-1865.* Viking, 2001.
Tackach, James. *The Emancipation Proclamation.* Lucent Bks., 1999. Younger readers.

Text of the Emancipation Proclamation

Whereas, on the twenty-second day of September, in the year of our Lord one thousand eight hundred and sixty-two, a proclamation was issued by the President of he United States, containing, among other things, the following, to wit:

That on the first day of January, in the year of our Lord one thousand eight hundred and sixty-three, all persons held as slaves within any State, or designated part of a State, the people whereof shall then be in rebellion against the United States, shall be then, thenceforward, and forever free; and the Executive Government of the United States, including the military and naval authority thereof, will recognize and maintain the freedom of such persons, and will do no act or acts to repress such persons, or any of them, in any efforts they may make for their actual freedom.

That the Executive will, on the first day of January aforesaid, by proclamation, designate the States and parts of States, if any, in which the people thereof respectively shall then be in rebellion against the United States; and the fact that any State, or the people thereof, shall on that day be in good faith represented in the Congress of the United States by members chosen thereto at elections wherein a majority of the qualified voters of such State shall have participated, shall in the absence of strong countervailing testimony be deemed conclusive evidence that such State and the people thereof are not then in rebellion against the United States.

Now, therefore, I, Abraham Lincoln, President of the United States, by virtue of the power in me vested as Commander-in-Chief of the Army and Navy of the United States, in time of actual armed rebellion against the authority and government of the United States, and as a fit and necessary war measure for suppressing said rebellion, do on this first day of January, in the year of our Lord one thousand eight hundred and sixty-three, and in accordance with my purpose so to do, publicly proclaimed for the full period of 100 days from the day first above mentioned, order and designate as the States and parts of States wherein the people thereof, respectively, are this day in rebellion against the United States, the following, to wit:

Arkansas, Texas, Louisiana (except the parishes of St. Bernard, Plaquemines, Jefferson, St. John, St. Charles, St. James, Ascension, Assumption, Terre Bonne, Lafourche, St. Mary, St. Martin, and Orleans, including the city of New Orleans), Mississippi, Alabama, Florida, Georgia, South Carolina, North Carolina, and Virginia (except the forty-eight counties designated as West Virginia, and also the counties of Berkeley, Accomac, Northampton, Elizabeth City, York, Princess Anne, and Norfolk, including the cities of Norfolk and Portsmouth), and which excepted parts are for the present left precisely as if this proclamation were not issued.

And by virtue of the power and for the purpose aforesaid, I do order and declare that all persons held as slaves within said designated States and parts of States are, and henceforward shall be, free; and that the Executive Government of the United States, including the military and naval authorities thereof, shall recognize and maintain the freedom of said persons.

And I hereby enjoin upon the people so declared to be free to abstain from all violence, unless in necessary self-defense; and I recommend to them that, in all cases where allowed, they labor faithfully for reasonable wages.

And I further declare and make known that such persons of suitable condition will be received into the armed service of the United States to garrison forts, positions, stations, and other places, and to man vessels of all sorts in said service.

And upon this act, sincerely believed to be an act of justice, warranted by the Constitution upon military necessity, I invoke the considerate judgment of mankind and the gracious favor of Almighty God.

In witness whereof, I have hereunto set my hand and caused the seal of the United States to be affixed.

Done at the city of Washington, the first day of January, in the year of our Lord one thousand eight hundred and sixty-three, and of the independence of the United States of America the eighty-seventh.

By the President: Abraham Lincoln

William H. Seward, Secretary of State.

Embalming, *ehm BAH mihng* or *ehm BAHL mihng,* is the artificial preservation of dead bodies. Embalming keeps a body lifelike in appearance when it lies in state prior to a funeral. Embalming also meets the requirements of some religions and retards decay so that a body may be shipped or kept several days for a funeral.

Ancient embalming. Embalming was a highly skilled profession in ancient Egypt as early as 2700 B.C. Egyptians believed that a *mummy,* or preserved body, was necessary for the survival of the soul. The embalming process varied according to the wealth or prominence of the deceased person. The embalmer dried the body by covering it with *natron,* a powdery mineral consisting of sodium carbonate and salt, and then filled the body cavities with oils, spices, and resins. The use of pitch and tars often gave the mummies a black appearance.

In 1880, the body of King Mer-en-re was found in his pyramid at Saqqarah where it had been preserved for 4,500 years. In 1881, archaeologists discovered at Dayr al Bahri the 3,200-year-old mummy of the Egyptian King Ramses II.

The ancient Greeks, Romans, and Israelites simply anointed dead bodies with spices, perfumes, and oils. The early Christians did not practice embalming because of their objection to mutilation of the dead.

Modern embalming began around 1700. A Dutch anatomist, Frederick Ruysch, devised a formula which, when injected into the arteries, would preserve a lifelike appearance of the deceased. Today, embalmers remove body liquids and then inject a fluid containing formaldehyde, mercuric chloride, zinc chloride, and alcohol. Embalming is taught in schools of mortuary science. A person then serves an apprenticeship and must pass a state board examination to receive a license to practice as a *mortician.* Embalming is not nearly as common in Europe as it is in the United States. But an increased number of cremations has led to fewer embalmings throughout the world. Richard A. Kalish

See also **Egypt, Ancient** (The afterlife); **Funeral customs; Mummy; Myrrh.**

Embargo is an order designed to stop the movement of goods. An embargo, issued by the government of one country, may restrict or suspend trade between that country and another nation.

One government may impose an embargo to hamper the military efforts of another. For example, the United States prohibits the export of weapons to countries that sponsor terrorism. Sometimes one government im-

poses an embargo to express its disapproval of actions taken by another government. The embargo is intended to pressure the offending government to change its actions. For example, the most significant embargo in U.S. history was the one authorized by Congress in 1807 to stop British and French vessels from interfering with U.S. trade (see **Embargo Act**).

In 1990, the United States and many other countries imposed an embargo against Iraq soon after Iraq had invaded Kuwait. As a result of the embargo, trade with Iraq fell sharply. However, Iraq held Kuwait until U.S. and other forces defeated Iraq in the Persian Gulf War in 1991. Ralph K. Beebe

Embargo Act was a law passed by Congress in 1807 that began the most famous embargo in United States history. The act prohibited all ships from entering or leaving American ports.

Congress passed the Embargo Act to put pressure mainly on Britain and France, which were fighting a war that also involved most other European nations. The act kept the United States out of the war, but it reduced the large profits American merchants had been making by trading with both sides.

Before 1807, Britain and France had been seizing U.S. merchant ships to prevent each other from obtaining American goods. The British also searched these ships for deserters from the British navy and forced them to return. But the British seized Americans as well and made them serve in the British navy.

In 1807, a British ship attacked the *Chesapeake,* an American naval vessel, after it refused the British ship's request to search for deserters. This act of war greatly angered the American public. But instead of asking Congress to declare war, President Thomas Jefferson recommended a general embargo. Congress enacted the measure in December 1807.

The embargo lasted 14 months. It was unpopular in many parts of the nation because it hurt the economy badly. Merchants began smuggling goods and thus weakened the effectiveness of the embargo. In 1809, Congress passed the Non-Intercourse Act. This act canceled the embargo for all nations except Britain and France. Three years later, the United States went to war against Britain. Ralph K. Beebe

See also **Blockade; Jefferson, Thomas** (Commercial retaliation) ; **War of 1812.**

Embassy. See **Ambassador.**

Embezzlement, *ehm BEHZ uhl muhnt,* is the crime committed when someone entrusted with another's money or property illegally takes it for personal use. It is not like a robbery, in which the robber takes money or property by force or threat. In an embezzlement, the owner has turned the property over to the embezzler.

Embezzlement is a modern crime. In early English common law, a person could not be charged with theft if the property taken had been legally entrusted, even though the person did not use the property in the way its owner wanted. However, business people needed a law to protect their property while their employees handled it. So the courts devised the crime of embezzlement. The punishment for embezzlement is imprisonment. Usually the penalty is the same as for larceny—a year or more in prison for a major theft and less than a year for a minor theft (see **Larceny**). Charles F. Wellford

Embioptera. See **Insect** (table).

Emblem. See **Symbol.**

Embolism, *EHM buh lihz uhm,* is a condition in which a blood vessel is blocked by material that has been carried there by the bloodstream. The blockage, which is called an *embolus,* may consist of a blood clot, air bubbles, clumps of bacteria, small drops of fat, cancer cells, or other foreign objects. The most serious embolisms occur in the brain, heart, kidneys, or lungs. A blood clot, the most common cause of an embolism, sometimes forms in a leg vein and travels to other blood vessels. Air bubbles may result from a chest or lung injury. Bacteria from a serious infection can accumulate in the blood and cause an embolism. Bone fractures may damage fat tissue, releasing drops of fat into the blood. Cancer cells that have broken loose from a tumor may cause an embolus. Dominick Sabatino

See also **Stroke.**

Embossing, *ehm BAWS ihng,* is a process in which a raised design is stamped or pressed on such materials as leather, paper, wood, or metal. One method of embossing is to press the material between two shaping tools, called *dies.* Letterheads and cards are embossed in this way. The paper is first dampened to make it more flexible. As the embossed area dries, it becomes as hard as the surrounding paper. Stamping machines are used to emboss coins because great pressure is required to raise designs on the metal (see **Die and diemaking**). Early Greek coins were embossed in dies held on an anvil. A similar process of embossing is used today.

Wood may be embossed by soaking it in water and then pressing a red-hot iron mold on it. Dies can also be used to emboss wood veneers and some plastics.

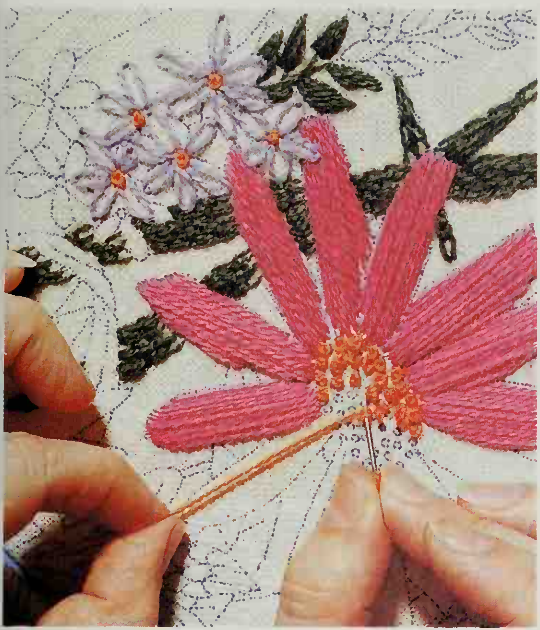
The term *repoussé* is sometimes used as a synonym for embossing, but this is not strictly correct. In embossing, the surrounding field is pressed back, leaving the design in relief. In repoussé, the design is beaten out from the back by hand. Patrick H. Ela

Embroidery is the art of stitching decorations on a fabric or similar material with a needle and thread. Stitches can be combined to make an unlimited variety of designs, including flowers, animals, people, and abstract patterns. The design is drawn on the fabric and then embroidered, or it is created during the embroidering process.

Since prehistoric times, most cultures have developed their own embroidery styles. People embroider clothing and use embroidered furnishings to decorate their homes and public buildings. Embroidered clothing ranges from simple undergarments to royal robes decorated with gold and silver threads. Embroidered furnishings include bed linens, chair covers, tablecloths, and wallhangings. Thousands of hours may be needed to richly embroider a garment or furnishing with millions of tiny stitches.

Traditionally, craftworkers and hobbyists embroider by hand. Today, however, machines do most embroidering of factory products. Home sewing machines can be equipped with special attachments for embroidery.

Materials. Fabric used for embroidery is called *backing fabric.* It can be any fabric through which the embroiderer can pull embroidery thread without damaging the fabric or thread. Common backing fabrics include cotton, linen, silk, and wool. Some people use card-



WORLD BOOK photo

Embroidery uses thread and a special needle to create decorative stitches on a fabric or similar material. This example combines the four basic embroidery stitches, (1) flat, (2) knotted, (3) chained, and (4) looped, to make a colorful floral design.

board, leather, and other materials. Embroidery threads range from thin strands to thick yarns. The most widely used threads include embroidery floss, linen, pearl cotton, and yarn. Various sizes of sewing needles are used for embroidery. The size chosen depends on the kind of backing fabric and thread being used.

Embroiderers select materials that are best suited for the finished product. For example, embroidered chair covers that get heavy use are made from durable fabrics and sturdy threads. Wallhangings are exposed to less wear than chair covers and can be made from any materials. Some people attach buttons, shells, or other objects to their embroidery. Embroiderers often stretch their backing fabric tightly across a stretcher frame or hoop before starting to stitch. This method is especially helpful for embroidering fine, detailed work. When working with large stitches on heavy fabrics, the embroiderer can spread the fabric loosely.

Embroidery stitches. There are only a few basic embroidery stitches, but hundreds of variations of them have been developed. Most stitches belong to one of four groups: (1) flat, (2) knotted, (3) chained, and (4) looped. Flat stitches lie straight and flat against the fabric. They can be made in any length and direction to fill in an area. Knotted stitches form knots of thread on the fabric surface and give textural effects to the embroidery. Chained stitches form loops that link together. Looped stitches are curved. Chained and looped stitches are used to outline and fill in designs. Dona Z. Meilach

Related articles in *World Book* include:

Appliqué	Hungary (picture)	Petit point
Beadwork	Needlepoint	Sampler
Crewel		

Embryo, *EHM bree oh,* is an animal or plant in an early stage of its development. The embryo is formed by sexual reproduction when a male sperm cell unites with a female egg cell, or *ovum.* This union is called *fertilization.* The fertilized egg, at first called a *zygote,* goes through a series of divisions that produce many cells. These developing cells, which form specialized structures and grow, are referred to as an embryo.

In flowering plants and conifers, the embryo is the part of the seed from which the mature plant develops. In other plants, such as ferns, the embryo is the mass of cells that develops into a new plant. See **Fern; Germination; Seed.**

In most fish and amphibians, the female releases many eggs into the water and some of the eggs are fertilized by sperm released at about the same time and place by the male. The embryo then forms and develops outside the female's body. In birds and most reptiles and insects, the embryo develops within an egg laid by the female. In almost all mammals, the egg is fertilized and the embryo develops inside the female's body. The human ovum is in an embryonic stage for about two months after fertilization. Thereafter it is called a *fetus* until birth. See **Reproduction, Human.** Julie M. Fagan

Embryo transfer. See **Breeding** (Animal breeding).

Embryology, *ehm bree AHL uh jee,* is the study of multicellular organisms during their early stages of development. A plant or animal is called an embryo until it develops all its essential tissues and organs. An unborn human is an embryo for about the first two months of its development. Scientists who specialize in embryology are called *embryologists.*

The study of embryology includes *experimental embryology* and *descriptive embryology.* Experimental embryology deals with the basic cell processes that control an embryo's development and growth. Cells divide and specialize, forming functional groups that develop into tissues and organs. This process is called *embryogenesis.*

Embryologists try to determine how embryogenesis is regulated. Much of their work involves experiments on animals, such as chickens and mice, whose embryonic development is similar to that of humans.

Descriptive embryology focuses on the normal sequence of events in the formation of organs during the embryonic period. Knowledge of the normal pattern of organ development in an embryo helps in understanding the structure and arrangement of organs in an adult. It also can help explain why certain birth defects occur.

Eva Botstein Griepp

Emerald is a rich green gemstone that is a variety of the mineral beryl. It owes its color to minute amounts of chromium in the crystals. Pure beryl is beryllium aluminum silicate. The value of an emerald lies in its color and its freedom from flaws and *inclusions* (other substances enclosed in the crystals). An emerald with a blue tint is more valuable than one with a yellow tint. Most emerald crystals contain minute fractures, which are sometimes called *veils,* and various kinds of inclusions. Perfect emeralds are very rare and therefore may be more expensive than diamonds. Emeralds are harder than quartz, but not as hard as sapphire.

The finest emeralds are obtained from Colombia. India, Russia, South Africa, and Zimbabwe also produce

emeralds. In the United States, North Carolina has produced some emeralds. Robert I. Gait

See also **Beryl; Birthstone; Gem** (picture).

Emerald Isle is a poetic name for Ireland. William Drennan (1754-1820) of Belfast claimed to have coined the name in this stanza of his poem "Erin" (1795):

> Arm of Erin! prove strong; but be gentle as brave,
> And, uplifted to strike, still be ready to save;
> Nor one feeling of vengeance presume to defile
> The cause, or the men, of the Emerald Isle.

The name is popular because of the deep green of Ireland's fields and trees. See also **Ireland**.

Emergency Medical Services refers to a system of emergency health care. This health care system involves community resources and medical workers who provide instant prehospital care to victims of injury or sudden illness.

The Emergency Medical Services (EMS) system is activated when a person calls a telephone number reserved for emergencies. In nearly half the United States, this number is 9-1-1. Some systems have a computer that displays the telephone number, address, and name of the owner of the phone used. Such computers are especially helpful if the caller cannot speak. A trained EMS dispatcher receives the call and sends an ambulance to the scene. EMS ambulances are equipped with lifesaving medical supplies and capable of ambulance-to-hospital communication.

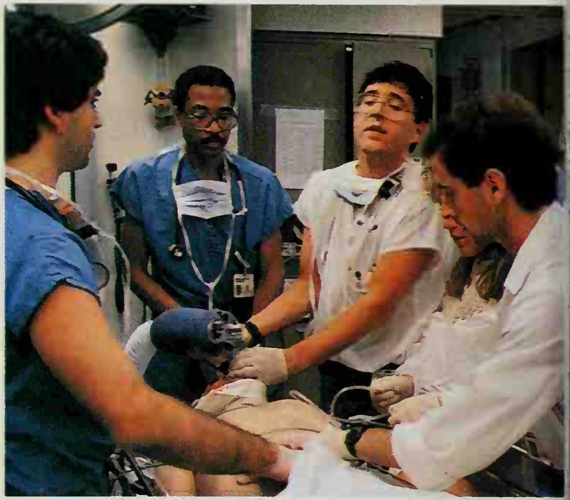
The system includes trained ambulance workers called emergency medical technicians (EMT's). EMT's are trained to provide basic first aid and to transport the victim to the nearest or most appropriate hospital. Some EMT's are trained in advanced skills. EMT-paramedics, also simply known as paramedics, can administer lifesaving drugs, help care for heart attack victims, and provide other forms of advanced care under the guidance of an emergency room physician.

EMS systems were introduced in the mid-1960's. Today, half of all U.S. families live within 10 minutes of an EMS system staffed with paramedics. S. Elizabeth White

Emergency room is a hospital department that provides immediate care when any delay of treatment could cause extreme suffering or threaten life. People can go to an emergency room—commonly called an ER—at any time of the day or night without an appointment. People typically seek emergency care for such urgent matters as suspected heart attacks, strokes, broken bones, severe pain, or serious wounds. In the United States, a federal law requires an ER to examine anyone requesting care.

Evaluation of patients begins as soon as they enter the ER. In many ER's, the first person whom a patient sees is a nurse with special skill in *triage (tree AHZH).* Triage involves deciding the order in which patients should be treated based on a preliminary judgment about the seriousness of their conditions. The sickest patients receive care first. Patients whose care can safely be put off for an hour or two must wait until more urgent cases have been seen. For example, a patient with symptoms of a heart attack would be treated before a person with a sprained ankle, regardless of who arrived first.

In addition to triage specialists and other nurses, emergency rooms are staffed by doctors, doctors-in-training, clerks, and technicians. The best ER's employ doctors and nurses who are specially trained in emer-



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Emergency room professionals often work as a team to care for the most critically ill or injured patients. Each team member provides essential treatment or supports vital body functions.

gency medicine. Providing emergency care requires skill in lifesaving techniques as well as wide knowledge of all types of illness and injury. In addition, ER professionals must make rapid decisions, act quickly, and remain calm in highly stressful situations.

When a patient's turn arrives, a doctor performs a thorough examination and identifies the problem. Emergency rooms are outfitted with the equipment and supplies needed to diagnose and treat an extremely broad range of illnesses and injuries. In an ER, results of X rays, blood tests, and other diagnostic procedures are reported to doctors immediately.

Some patients go home after appropriate emergency treatment—for example, after a deep cut has been cleaned and stitched. These patients can see their own doctors later for any further care needed. Patients who require more extensive treatment may be admitted to other departments of the hospital.

In certain developed countries, many people rely on emergency rooms for nonemergency care. Some of these patients seek care in an ER because they have no personal doctor and so have difficulty getting an appointment to see one when they are sick. Other patients feel that they are too sick or injured to wait for their doctor to see them during normal office hours.

Richard M. Feldman

Emerson, Ralph Waldo (1803-1882), ranks as a leading figure in the thought and literature of American civilization. He was an essayist, critic, poet, orator, and popular philosopher. He brought together elements from the past and shaped them into literature that had an important effect on later American writing. He influenced the work of Henry David Thoreau, Herman Melville, Walt Whitman, Emily Dickinson, Henry James, and Robert Frost.

Emerson's essays are a series of loosely related impressions, maxims, proverbs, and parables. He has been described as belonging to the tradition of "wisdom literature" that includes Confucius, Marcus Aurelius, Michel

de Montaigne, and Francis Bacon, among others.

Despite personal hardships, Emerson developed a moral philosophy based on optimism and individualism. In "Self-Reliance," he wrote, "Nothing is at last sacred but the integrity of your own mind," and, "Whoso would be a man, must be a nonconformist."

His life. Emerson was born in Boston. His early life was marked by poverty, frustration, and sickness. His father, a Unitarian minister, died in 1811, leaving Emerson's mother to raise five sons. One of his younger brothers spent most of his life in mental institutions. Another brother, also a victim of mental illness, died in 1834. A third brother died in 1836 of tuberculosis.

Until Emerson was 30, he also suffered from poor health, including a lung disease and periods of temporary blindness. In addition, his first wife, Ellen, died in 1831 and his first son, Waldo, died in 1842. Emerson wrote one of his finest poems, "Threnody," for his son.

In 1817, Emerson entered Harvard College, where he developed lifelong interests in literature and philosophy. After graduating in 1821, he taught school briefly and then returned to study theology at the Harvard Divinity School. In 1826, he was licensed to preach. In 1829, he was ordained Unitarian pastor of the Second Church of Boston. For personal and religious reasons, Emerson grew dissatisfied with this profession and resigned his pulpit in 1832. After one year's travel in Europe, Emerson began a career as a writer and lecturer.

His prose works. The sources of Emerson's thought have been found in many intellectual movements—Platonism, Neoplatonism, Puritanism, Renaissance poetry, mysticism, idealism, skepticism, and romanticism. His prose style was active, simple, and economical.

His first book, *Nature* (1836), was received with some enthusiasm, particularly by the young people of his day. The book expressed the main principles of a new philosophical movement called *transcendentalism.* Soon after its publication, a discussion group was formed with Emerson as its leader. It eventually came to be called the "Transcendental Club." The club published an influential magazine, *The Dial,* devoted to literature and philosophy. Emerson edited the periodical from 1842 to 1844. See **Transcendentalism**.

In the 1830's, Emerson gained a solid, though controversial, reputation as a public lecturer and a young man with remarkably forceful and original ideas. In 1837, he gave a famous address at Harvard called "The American Scholar," in which he outlined his philosophy of humanism. He said that independent scholars must interpret and lead their culture by means of nature, books, and action. He urged his listeners to learn directly from life, know the past through books, and express themselves through action. In this address, he proclaimed America's intellectual independence from Europe. In the so-called "Divinity School Address" (1838), he attacked "historical Christianity." He favored a new religion founded in nature and fulfilled by direct, mystical intuition of God, and opposed formal Christianity's emphasis on ritual.

Emerson's next two books, *Essays* (1841 and 1844), contain much of his most enduring prose. In "Compensation," "Spiritual Laws," and "The Over-Soul," he stated his faith in the moral orderliness of the universe and the divine force governing it. In "Experience," perhaps his best essay, Emerson allowed room for skepticism and showed how doubts are conquered through faith. In "Art" and "The Poet," he outlined his philosophy of aesthetics, and in "Politics" and "New England Reformers," he explained his social philosophy.

Emerson's later prose works are more specialized and better organized. *Representative Men* (1850) is a series of semibiographical, semicritical essays on Plato, Emanuel Swedenborg, Montaigne, William Shakespeare, Napoleon, and Johann Wolfgang von Goethe. They are linked by Emerson's thesis that "great men" teach us to "correct the delirium of the animal spirits, make us considerate and engage us to new aims and powers." In *English Traits* (1856), Emerson recorded his two voyages to Europe and discussed English literature, character, customs, and traditions.

His poetry. Though in theory Emerson believed that "it is not metres, but a metre-making argument that makes a poem," he wrote his verse in traditional forms. His poetry is characterized by conventional rhythms, rhyme patterns, and stanza forms, as well as economy of phrasing and simplicity of imagery.

The two volumes of poetry that appeared during his lifetime, *Poems* (1846) and *May-Day* (1867), contain some of the finest American verse of the 1800's. He developed his mystical religion in "Each and All," "Hamatreya," and "Brahma." He celebrated nature in "The Rhodora," "The Humble-Bee," "The Snow-Storm," and the two parts of "Woodnotes." The poems "Uriel," "The Problem," and "The Sphinx" are among Emerson's most personal expressions, reflecting his frustrations, doubts, and longings. Like these, "Days" reveals a comic portrait, perhaps unintentional, of himself and of his failure to fulfill his "morning wishes." "Days" is often considered Emerson's greatest poem. John Clendenning

Additional resources

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Emery, *EHM uhr ee* or *EHM ree,* is a hard black or gray rock that consists chiefly of the minerals corundum, magnetite, and, in some cases, spinel. Its hardness depends on the amount of corundum. People use emery as an *abrasive* (grinding and polishing material). When used for grinding, emery is crushed into small grains and glued onto cloth or paper. The grains may be mixed with clay to produce grinding wheels. For use in polishing, emery is reduced to a fine powder. Certain other substances are gradually replacing emery as an abrasive. In the United States, the major use of emery is to give traction to stairs and pavement.

Emery occurs in only a few places. These include Russia, Turkey, the United States, and Cape Emeri, Greece, for which it is named. Maria Luisa Crawford

Emetic, *ih MEHT ihk,* is a medicine used to produce vomiting. Emetics rid the stomach of poisons or irritating foods. Emetics cause vomiting in two ways: (1) They can irritate the lining of the throat and stomach and cause vomiting as a reflex action. (2) They can stimulate the vomiting center in the *medulla* (lower part of the brain) so that nerve impulses cause the muscles of the abdominal wall, diaphragm, and stomach wall to con-

tract. This pushes the contents out. One of the most widely used emetics is the drug ipecac (see **Ipecac**). Two tablespoons (30 milliliters) of dry mustard in 1 pint (0.5 liter) of water is another common emetic. An emetic should not be given to someone who has taken a petroleum product, a strong acid, or a corrosive poison such as lye. Barbara M. Bayer

Emigration. See **Immigration.**

Émigrés, *EHM uh grayz,* were people who fled France because of the French Revolution. The emigration began after the fall of the Bastille, a hated Paris prison, on July 14, 1789. The émigrés included people of every social class, but many were clergy or nobles who feared for their lives. Outside France, they became important in stirring up other governments against the revolutionary government in France. In 1792, an Austro-Prussian army invaded France. The émigrés persuaded its commander, the Duke of Brunswick, to threaten to level Paris if King Louis XVI was harmed. The declaration led the Parisians to depose the king and to organize a "commune," a governing council that held power for over a month. The threat also caused them to demand a convention to give France a new constitution. As the French Revolution became more radical, some moderate revolutionaries emigrated. Among them was the Marquis de Lafayette.

After 1800, Napoleon I allowed the émigrés to return to France if they would serve him loyally. Most émigrés returned. But some did not. These included members of the royal Bourbon family who plotted against Napoleon. Their land was seized, and their relatives became subject to arrest. When the Bourbons returned after Napoleon's fall, they wanted their land back. But they received money instead of the land. Eric A. Arnold, Jr.

Emin Pasha, *eh MEEN pah SHAH* (1840-1892), was a German colonial administrator and explorer in Africa. He made important contributions to the geographical knowledge of the Sudan and central Africa.

Emin Pasha's given name was Eduard Schnitzer, and he was born in Oppeln, Silesia (now Opole, Poland). He became a physician in Albania, then a province of Turkey. The people there called him *Emin* (faithful one). By 1875, Emin had moved to the Sudan, which was ruled by Egypt. In 1876, he joined the staff of Colonel Charles G. Gordon, administrator of the southern Sudanese province of Equatoria. Emin became *pasha* (governor) of Equatoria in 1878 and began his explorations.

A spreading Sudanese uprising in 1885 forced Emin to retreat southward into what is now Uganda. In 1888, a search party led by Henry Morton Stanley reached Emin. Stanley, an adventurous journalist who had gained fame for finding David Livingstone in Africa, persuaded Emin to leave the interior. In 1890, Emin joined the German East Africa Company, which controlled what is now Tanzania. He led an expedition to the upper Congo River region and was killed by Africans. Robert I. Rotberg

Eminent domain, in the United States, is the power of a government to take private property for public use. According to law, the government must pay the owner a fair price for the property taken. Federal, state, and most local governments have the power of eminent domain. Governments often use eminent domain to acquire land for such public works as roads, dams, and urban renewal. In some cases, governments give the power of eminent domain to corporations that intend to use privately owned land for projects that benefit the public. Such projects include the construction of railroads, schools, and electric power plants.

A government may take over property that an owner refuses to sell in a process called *condemnation.* A court typically appoints appraisers to set a fair price for the property or holds a jury trial to determine one (see **Appraisal**). The owner must give the property to the government in return for the price set by the appraisers or jury. In Canada, the taking of private property for public use is called *expropriation.* Linda Henry Elrod

See also **City planning** (Governmental authority).

Emission control. See **Automobile** (Environmental impact; The exhaust system).

Emmet, Robert (1778-1803), an Irish patriot, became one of that country's best-remembered heroes. He led an unsuccessful revolt against the English viceroy in 1803. Although Emmet escaped after the revolt, he was later captured, tried, and hanged.

Detail of an engraving (about the 1830's) by Thomas Kelly; Bettmann Archive

Robert Emmet

Emmet was born in Dublin. As a young man, he became disturbed over the injustice of English rule. He joined the United Irishmen and later sought aid in France in an effort to free Ireland. Thomas E. Hachey

Emmett, Daniel Decatur (1815-1904), an American minstrel performer and songwriter, wrote "Dixie" (1859). It became the war song of the South in the Civil War. He wrote many other songs, including "Old Dan Tucker." Emmett was born in Mt. Vernon, Ohio. In 1843, he became an original member of the Virginia Minstrels, considered the first true American minstrel company. In 1859, he joined Bryant's Minstrels, for whom he wrote "Dixie." See also **Dixie; Minstrel show.** Gerald Bordman

Emmy. See **Television** (Television awards).

Emory University is a private, coeducational university in Atlanta, Ga. It is affiliated with the United Methodist Church. The university includes a college of arts and sciences; a graduate school; and schools of business administration, law, medicine, nursing, public health, and theology. Emory also has a medical complex, a museum of art and archaeology, and other research institutes. Near the campus is the Carter Center of Emory University, a research center that former President Jimmy Carter helped establish. Oxford College, a two-year division of the university, is in Oxford, Ga., where Emory was founded in 1836.

Critically reviewed by Emory University

Emotion is usually considered to be a feeling about or reaction to certain important events or thoughts. An emotion can be either pleasant or unpleasant. An individual also may have a mixture of both pleasant and unpleasant emotions. People enjoy feeling such pleasant emotions as love, happiness, and contentment. They often try to avoid feeling unpleasant emotions, such as loneliness, worry, and grief. However, people are sometimes not fully aware of their own emotions. Although

most people believe they know what an emotion is, psychologists have not yet agreed on a definition that applies to both human beings and other animals.

Individuals communicate most of their emotions by means of words, a variety of other sounds, facial expressions, and gestures. For example, anger causes many people to frown, make a fist, and yell. People learn ways of showing some of their emotions from members of their society, though heredity may determine some emotional behavior. Research has shown that different isolated peoples show emotions by means of similar facial expressions. Even children who are born blind have facial expressions like those of sighted children.

Early theories about emotions. Charles Darwin, the British scientist who developed the theory of natural selection, also studied emotion. In his book *The Expression of the Emotions in Man and Animals* (1872), Darwin said that emotional behavior originally served both as an aid to survival and as a method of communicating intentions. For example, angry people show their teeth because they inherited behavior patterns that their prehistoric ancestors needed for fighting. Bared teeth also signal an intention to attack.

During the 1880's, the American psychologist William James and the Danish physiologist Carl G. Lange independently reached another conclusion about emotions. According to their theory, the *James-Lange theory of emotions,* people feel emotions only if aware of their own internal physical reactions to events, such as increased heart rate or blood pressure.

Some psychologists still believe in the James-Lange theory, but there is little evidence to support it. The theory was not upheld by research on cats that had their *autonomic nervous system* damaged. This system controls such body functions as breathing and digestion, which change when people feel an emotion. Cats in the experiment could not feel their body's internal changes, but they showed normal emotional behavior.

John B. Watson, an American psychologist who helped found the school of psychology called *behaviorism,* believed emotions were *psychophysical* (mental and bodily) reactions to specific events. He observed that babies stimulated by certain events, such as falling, having their arms held tightly, or being stroked, showed three basic emotions. He labeled these emotions *fear, anger,* and *love.* Watson's view that there are only three basic emotions has been challenged frequently since he proposed it in 1919.

In 1927, the American physiologist Walter B. Cannon and his associate Philip Bard proposed the *Cannon-Bard theory of emotions.* Cannon and Bard thought emotions arose only when the *hypothalamus,* a part of the brain, was stimulated. They believed the hypothalamus was the "seat" of emotions. Several researchers have since shown that stimulation of different parts of the brain, especially the *limbic system,* triggers emotions.

Modern theories about emotion. In 1962, the American psychologist Stanley Schachter proposed a *two-factor theory of emotion,* based on an experiment he conducted with Jerome E. Singer. The two factors that determine different emotions, he claimed, are physical changes in a person's body plus the reason the individual gives for those changes. This theory states that emotions result from people's interpretations of their situations after they have been physiologically stimulated. Later research shows that the physiological stimulation may be less important than originally thought.

The most widely accepted view is that emotions occur as a complex sequence of events. The sequence begins when a person encounters an important event or thought. The person then interprets the meaning of the encounter, and the interpretation determines the feeling that is likely to follow. For example, someone who encounters a bear in the woods would probably interpret the event as dangerous. The sense of danger would cause the individual to feel fear. Each feeling is followed by physical changes and impulses to action, which are responses to the event that started the sequence. Thus, a person who met a bear would probably run away, which would increase the person's chances of survival.

Several American psychologists, including Carroll E. Izard, Robert Plutchik, and Silvan S. Tomkins, have independently developed the theory that there are eight basic emotions. These emotions—which can exist at various levels of intensity—are anger, fear, joy, sadness, acceptance, disgust, surprise, and interest or curiosity. They combine to form all other emotions, just as certain basic colors produce all others. Robert Plutchik

See also **Brain** (In producing emotions); **Psychosomatic medicine.**

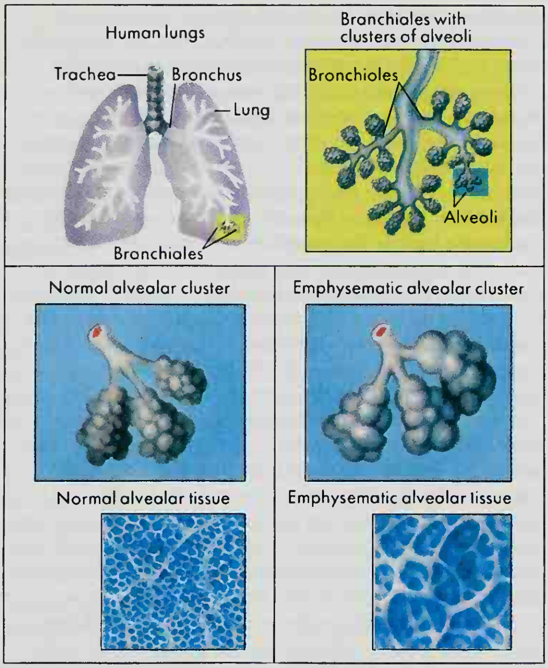
Empedocles, *ehm PEHD uh KLEEZ* (495?-435? B.C.), was an early Greek philosopher. He agreed with Parmenides, an influential Greek philosopher, that what exists is eternal and unchanging. But Empedocles explained the experience of change by rejecting Parmenides' notion that the universe consists of one basic substance. Empedocles became the first philosopher to argue that what exists can be reduced to four elements—air, earth, fire, and water. He said that all other substances result from temporary combinations of these elements. The elements are eternal and unchanging, but their combining and separating appear as change.

Empedocles said that a force called *love* causes the elements to come together as compounds, and that a force called *strife* causes the compounds to break up. He believed that the universe undergoes a continuous cycle from complete unification of the elements under the domination of love to complete separation of the elements under strife. The world we live in occurs between these two extreme states. Empedocles was born in the Greek city Acragas, in Sicily. Carl A. Huffman

See also **Pre-Socratic philosophy.**

Emperor is the ruler of an empire, or group of nations or states. A *king* usually rules only one area or people, but an emperor rules several. The word comes from the Latin word *imperator,* meaning *commander.* Emperor represented a military command in early Roman times, but later came to be the title of a ruler. After the fall of the Roman Empire in the West, in A.D. 476, the title passed out of use in Europe for several hundred years. In A.D. 800, Charlemagne had himself crowned emperor of the Romans. Since 1800, emperors have ruled China, France, Germany, Japan, and Russia at one time or another. The wife of an emperor or a woman who rules an empire is called an *empress.* See also **Empire.**

Emphysema, *EHM fuh SEE muh,* is a lung disease in which victims have difficulty breathing, especially when they exhale. Emphysema is one of the two main forms of



WORLD BOOK illustrations by Charles Wellek

How emphysema affects the lungs. Emphysema destroys the walls of *alveoli* (air sacs) in the lungs. This results in the formation of large air spaces that trap carbon dioxide in alveoli and obstruct the flow of oxygen. The drawings include close-ups of alveoli in a healthy lung and in one with emphysema.

chronic obstructive pulmonary diseases. The other is *chronic bronchitis* (see **Bronchitis**). Most people with chronic obstructive pulmonary diseases suffer from both emphysema and chronic bronchitis. Chronic obstructive pulmonary diseases are characterized by progressive narrowing of the *airways*—that is, the tubes that connect the lungs to the nose and mouth.

Chronic obstructive pulmonary diseases are a major cause of death in the United States. An estimated 75,000 Americans die from these diseases each year. Smokers are at least 10 times more likely than nonsmokers to get the diseases. Symptoms usually do not appear until about the age of 50 and most victims are men.

How emphysema affects breathing. When fresh air is inhaled, it is carried through the airways to small air sacs, called *alveoli,* in the lungs. The walls of these air sacs contain a network of tiny blood vessels called *pulmonary capillaries.* As the blood in the pulmonary capillaries moves along the walls of the air sacs, oxygen from the inhaled air leaves these alveoli and enters the blood. At the same time, carbon dioxide moves from the blood into the alveoli. The oxygen in the blood is distributed to tissues throughout the body by the arteries. Carbon dioxide from the alveoli is carried through the airways to the nose and mouth and then out of the body when a person exhales. See **Respiration.**

Emphysema destroys the walls of air sacs, including the pulmonary capillaries. Because a healthy adult has several hundred million air sacs, this process may occur for many years before a person suffering from emphysema experiences any difficulty breathing. As the disease progresses, the alveolar walls with their capillaries are destroyed. This results in obstruction of airways because the alveolar walls help hold small airways open. It also results in the formation of large, inefficient air spaces that trap air, containing carbon dioxide, inside the lung. The lung begins to lose elasticity and becomes overinflated as more air is inhaled and trapped in the air spaces. Thus, emphysema disrupts the flow of carbon dioxide from the body and deprives body tissues of needed oxygen.

Symptoms of emphysema include difficulty in breathing, especially during exhalation; shortness of breath; an enlarged chest; and a bluish skin color resulting from a less than normal amount of oxygen in the blood. Emphysema victims often suffer from frequent colds and lung infections. Some also develop serious heart disease.

Causes of emphysema are not fully understood. Cigarette smoking, air pollution, environmental or occupational hazards, repeated infections, and genetic factors may all play a role. Many scientists believe that certain enzymes in the body destroy the alveolar walls in emphysema victims. Factors that cause the disease may affect the body's ability to control these enzymes.

Treatment. Emphysema cannot be cured, but treatment may help reduce further lung damage. Victims of emphysema should avoid cigarette smoking and air pollution. They also should promptly treat recurrent colds and infections. Many victims are helped by drugs, physical therapy, special breathing techniques, and by breathing oxygen-enriched air. Michael G. Levitzky

Empire is a domain made up of different countries or states, held together and ruled by the strongest nation in the group. The word comes from a Latin word meaning a *dominion* or a *command.* History has seen the rise and fall of many great empires, such as those of Egypt, Rome, Germany, and Japan. In modern times, Britain, the Netherlands, France, and other countries built up colonial empires. See also **Emperor; Imperialism.**

Allen J. Greenberger

Empire State Building is a famous landmark in New York City. It was the tallest building in the world at the time of its completion and for many years afterward. The 102-story building measures 1,250 feet (381 meters) from the sidewalk to the roof. The Empire State Building is located on Fifth Avenue between 33rd Street and 34th Street.

The architectural firm of Shreve, Lamb & Harmon designed the Empire State Building, which was completed in 1931. It is a fine example of art deco, a sleek geometric style popular in the 1920's and 1930's. The building rises in a series of steplike shapes called *setbacks* to a slender tower topped by a metal spire. Panels of limestone and an alloy of chrome, nickel, and steel cover the skyscraper's riveted steel framework. The construction is so strong that only two floors suffered serious damage when a bomber crashed into the 79th floor in 1945.

Leland M. Roth

Empiricism, *ehm PIHR uh sihz uhm,* is a philosophical approach that views experience as the most important source of knowledge. It is the philosophical outlook of most scientists. Empiricists try to answer as many questions as possible by using information gathered by the senses. They reject attempts to decide issues on the

basis of pure reason or religious or political authority.

Empiricists disagree sharply about how experience is employed in the growth of knowledge. One group of empiricists believes that experience gained through the senses is the source of all knowledge and that all legitimate knowledge must be verifiable by sense experience. This view developed from the philosophies of George Berkeley, David Hume, John Locke, and Bertrand Russell of the United Kingdom; and Ernst Mach and philosophers called *logical positivists* in Austria. Such empiricists rely on several *presuppositions* (assumptions) that have been challenged by critics.

One presupposition is that all legitimate statements must be derivable from sense experience. However, critics have pointed out that science includes many laws that cannot be verified by experience alone. A second presupposition states that sense observations are conclusive and free from theory so that theories can reliably be built on them. However, critics say that all observations are influenced by scientific theory and so cannot provide a theory-free basis for knowledge. A third presupposition identifies what is real with what can be experienced through the senses. This idea has led many empiricists to deny the existence of a world outside our perceptions. Many scientists criticize this position because they think it runs counter to the spirit of science.

Another group of empiricists believe that the role of sense experience and experimentation is not to justify, verify, or defend knowledge. Instead, their role is to expose theories to sharp criticism. Philosophers in this group include William Whewell of the United Kingdom, Charles Sanders Peirce of the United States, and Ludwig Boltzmann and Karl Popper of Austria.

Empiricists in this group concentrate on proving theories false, rather than true. Their approach enables them to distinguish between what is real and what can be experienced. As a result, scientific discussion is not limited to what can be observed. These empiricists say that many important theories in the history of science have been based on factors that, at least at first, could not be perceived. The theory of the atom is one example.

W. W. Bartley III

Related articles in *World Book* include:

Berkeley, George	Mach, Ernst	Russell, Bertrand
Hume, David	Philosophy (Modern philosophy)	
Locke, John		

Employee benefits. See Pension; Profit sharing; Employee Stock Ownership Plan; Labor movement (Arranging contracts).

Employee relations. See Personnel management.

Employee Stock Ownership Plan (ESOP) is a worker benefit program. It allows workers to own part or all of a company's stock. It is designed to encourage productive work and reward length of service.

An ESOP borrows money from a bank or other commercial lender to buy stock in the company. It repays the loan from money the company contributes to the ESOP out of earnings and profits. The company may deduct a certain amount of the ESOP payments from its annual taxable income. Every year, the ESOP gives participating employees shares of the cash and stock it has acquired in the previous year. The number of shares each worker gets is based on the percentage of his or her salary compared to the total amount of salaries of the employees in the ESOP. A trust holds all the cash and stock paid to the ESOP.

Generally, employees gain possession of their stock when they retire or otherwise end their employment. In some plans, they may hold the stock as long as they wish and get any dividends the company pays on it. The employees also may sell or transfer ownership of the stock. The worth of the stock is determined by its fair market value. In some ESOP's, the company must buy the stock from former employees who want to sell it.

ESOP's differ from one another according to four main elements. These elements are (1) the amount of worker ownership of the company, (2) whether workers have voting rights for their stock, (3) the degree of worker control of the board of directors, and (4) the degree of labor-management cooperation to achieve goals.

Louis Kelso, an American lawyer and investment banker, created the ESOP concept during the 1950's. In 1974, Congress passed the first of several laws that provide tax incentives for firms that form ESOP's. Today, the United States has about 7,000 ESOP's, with about 10 million participating workers. Joseph Raphael Blasi

Employment. See Careers; Unemployment.

Employment agency, also called a *placement office,* is a service that finds jobs for workers and workers for jobs. It arranges interviews between candidates qualified for particular jobs and employers who have those jobs available. Private agencies charge a fee paid either by the candidate or by the employer. Most colleges and universities offer free placement service to their students. Also, many governments operate public employment offices. In the United States, these offices are financed by federal taxes and are administered by each state, in cooperation with the U.S. Department of Labor.

Many private employment agencies are listed in telephone books and newspapers, and with government licensing bureaus. A number of private, public, and student employment agencies have their own Internet Web sites, where they advertise job opportunities, identify candidates, and contact job seekers for interviews.

Once a potential match is found, a placement counselor with the employment agency meets with the candidate. The agency may give vocational tests and check the job seeker's references. The agency has files containing descriptions of available jobs, which are supplied by employers. Many agencies automate the office process by using computers for certain tasks. If the applicant meets the requirements for a job, the agency schedules an interview with the employer.

Employment service dates back to ancient times. Symbols scratched on lumps of clay found among the ruins of ancient Babylon indicate there was personnel placement at that time for laborers and servants. As early as 1800, Boston and New York City newspapers carried advertisements by people who found jobs for laborers, servants, and agricultural workers. Harvey A. Menden

Employment Service, United States, also called USES, is an agency of the Employment and Training Administration of the Department of Labor. USES sets policies for the nation's public employment service system. This system provides placement and funding services to job seekers, and recruitment and referral services to employers with job openings.

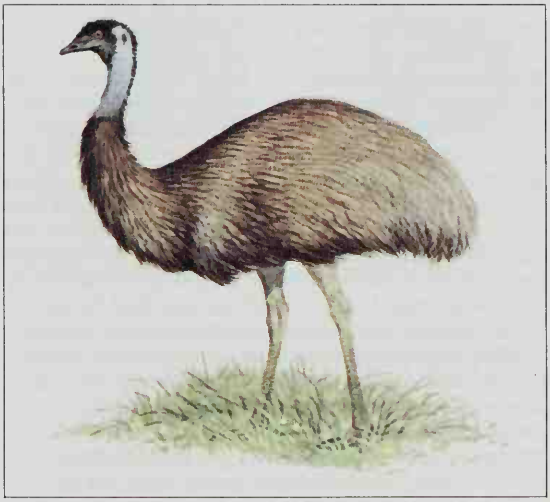
USES provides leadership to state employment serv-

ices, and it develops and explains national employment policies. The agency works closely with employer associations to provide assistance to the business community. It also tries to achieve equitable job opportunities for such groups as disabled people, veterans, young people, and various minority groups.

The USES programs are implemented through about 2,000 local offices. Many offices use computerized *job banks,* which store information about unfilled jobs. An interstate job bank distributes information nationwide about jobs that are not readily filled in the local area.

Critically reviewed by the United States Employment Service

Emu, *EE myoo,* is a large Australian bird that cannot fly. The emu stands about $5\frac{1}{2}$ feet (1.7 meters) high and weighs about 100 pounds (45 kilograms). The ostrich is the only taller bird. The emu has brownish black, thick feathers. Two feathers grow from each opening in the skin. The bird's small wings are hidden in feathers. The emu has long legs, and it is a swift runner.



WORLD BOOK illustration by Trevor Boyer, Linden Artists Ltd.

The emu can run swiftly, but it cannot fly.

The female emu lays between 8 and 10 green, rough-surfaced eggs in a flat nest of grass and leaves. Several females may lay eggs in a single nest. The male sits on the eggs until they hatch. Emus feed on fruit and green plants. They are considered pests because they eat crops and break down sheep fences.

Scientific classification. The emu is in the emu family, Dromaiidae. It is *Dromaius novaehollandiae.* John W. Fitzpatrick

See also **Cassowary; Ostrich.**

Emulsion, *ih MUHL shuhn,* is a preparation of one liquid evenly dispersed in another. The two liquids do not dissolve in each other. Rather, tiny drops of the dispersed liquid remain suspended in the other liquid. These drops range in size from $\frac{1}{10}$ to 20 *microns.* A micron equals $\frac{1}{1,000}$ of a millimeter or $\frac{1}{25,400}$ of an inch.

Some common substances such as cosmetic lotions, foods, lubricants, medicines, and paints are emulsions. Photographic film is coated with a light-sensitive colloid that is incorrectly called an emulsion.

Emulsions are not permanently stable. The liquids separate from each other after a certain time. To help keep them mixed, an *emulsifying agent* is needed.

Oil and water form the most common emulsions. An emulsion can be formed by either droplets of oil dispersed in water or droplets of water in oil. Milk is an emulsion of butterfat in water. The emulsifying agent that keeps butterfat suspended in milk is the protein *casein.* Robert J. Ouellette

See also **Colloid; Photography** (Exposing the film); **Suspension.**

Enabling act is a law that authorizes, or *enables,* individuals or groups to do things they would otherwise have no power to do. The United States Congress passed enabling acts to allow territories to set up the machinery for becoming states. These acts defined the boundaries of the new states. They also gave the people of the territories the right to elect delegates, hold a constitutional convention, and draw up a state constitution. A separate enabling act had to be passed for each territory before it became a state. Douglas Greenberg

Enamel is a glasslike substance used primarily to form a smooth, glossy surface on metal. It can be any of various colors and is used to decorate many kinds of articles, including metal cups, dishes, and plates. Enamel also provides a tough protective surface for bathroom fixtures, kitchen appliances, various types of industrial equipment, and many other items. Metal articles decorated or protected with enamel are called *enamelware* or, simply, *enamels.* The word *enamel* is often used to refer to the glasslike substance applied to ceramics. However, the correct name for this substance is *glaze.* The word *enamel* also refers to a type of paint that forms a hard, glossy surface when dry. This enamel paint can be applied over a glaze as a decoration.

Composition and application. Enamel is composed chiefly of powdered lead-soda glass or lead-potash glass. Minerals called *metallic oxides* are added to enamel to produce desired colors.

Enamel is applied to metal at a temperature of about 1500 °F (816 °C), and so only metals able to withstand this temperature can be enameled. Such metals include copper, gold, and platinum. Heat causes the enamel to melt and bond with the surface of metal. Enamel can be applied by sprinkling it evenly on a metal object that has

Casket (early 1500's) 7 in. (18 cm) long; The Art Institute of Chicago

An enameled casket made in Limoges, France, is decorated with scenes of the Biblical kings Solomon and David.

been preheated. It can also be liquefied and painted on a metal article, which is then *fired* (heated).

Techniques. There are five main decorative enameling techniques. They are (1) champlevé, (2) basse-taille, (3) cloisonné, (4) plique-à-jour, and (5) painting.

Champlevé (pronounced *SHAMP luh VAY*) begins with the artist cutting a design into the metal by engraving or a similar method. The cutaway portion is filled with enamel. After the object has been fired, the enamel is polished down to the level of the surrounding uncut metal. The city of Limoges, France, was a famous center of champlevé enamelware from the 1100's to the 1300's.

Basse-taille (*bahs TY*) is a refinement of champlevé. It involves applying an almost transparent colored enamel over the raised design of a metal article, usually gold or silver. The enamel lightly colors the high parts of the design and darkens the low areas, thus creating the effect of light and shade. The method was probably developed by Italian artists in the late 1200's.

Cloisonné (*KLOY zuh NAY*) uses a design made of wire, which is bent into small, connected compartments called *cloisons*. The design is fastened to the surface of a metal article, and enamel is applied to it. After the article has been fired, the enamel is polished until the top of the wire form is exposed. The form outlines the design and keeps the colors from running together. The art of cloisonné developed in the Near East.

Plique-à-jour (*PLEEK ah ZHOOR*) is produced by forming an object out of wire and filling the spaces with colored enamel. Firing then bonds the enamel to the wire. Plique-à-jour produces a glittering stained-glass effect because there is no solid backing to stop the light. It originated in France, probably in the 1300's.

Painting involves painting a design on a metal article with enamel and then firing the article to make the design permanent. Metal objects painted with enamel are called *surface-painted enamels*. English enamelers of the 1700's and early 1800's made beautiful surface-painted enamels, particularly such items as gold snuffboxes and copper boxes. William C. Gates, Jr.

Encephalitis, *ehn SEHF uh LY tihs,* is an inflammation of the brain. Many victims of encephalitis suffer only mild fever and headache for a few days. But encephalitis can cause convulsions, coma, and even death. There are many kinds of encephalitis. Most result from virus infections. Bacteria, harmful chemicals, and various tiny parasites can also cause the disease.

Symptoms of encephalitis include drowsiness, fever, headache, and muscle weakness. In addition, the disease may cause jerky movements; mental confusion; paralysis; and difficulty in hearing, seeing, speaking, and swallowing. Some victims suffer permanent brain damage, but the majority do not. Treatment depends on the nature of the specific cause of the disease.

Some viruses that cause encephalitis occur in the blood of certain kinds of animals, including birds and horses. They are transmitted to a human being by the bite of a mosquito that has previously bitten an infected animal. In some cases, viruses of such diseases as measles and mumps attack the brain and cause encephalitis. The disease can also occur as a complication of a vaccination. The symptoms of a few kinds of encephalitis appear months or even years after the infecting virus has entered the body. Such viruses are called *slow viruses.*

Viruses that cause encephalitis in human beings can bring about related diseases in animals. In 1971, an outbreak of *Venezuelan equine encephalomyelitis,* an inflammation of the brain and spinal cord, killed hundreds of horses in Texas.

Encephalitis is closely related to meningitis, an inflammation of the membranes that cover the brain and spinal cord (see **Meningitis**). When both the brain and the membrane covering it are inflamed, the disease is called *meningoencephalitis.* Marianne Schuelein

Encephalograph. See Electroencephalograph.

Enclave, *EHN klayv,* is a territory belonging to one country but lying within the boundaries of another country. For example, Gibraltar is a British enclave on the coast of Spain (see **Gibraltar**). Enclaves were once common in Europe and other areas. In most cases, rulers permitted passage through their territory to the enclaves within it. Today, nations believe that the presence of foreign territories within their boundaries violates national sovereignty.

During the 1500's and 1600's, France and Portugal established several enclaves in India. India claimed these territories after it won independence from the United Kingdom in 1947. France surrendered its enclaves in 1954. But Portugal kept its enclaves until 1961, when Indian troops seized them. Today, the few remaining enclaves include the Spanish territories of Ceuta and Melilla, which lie in Morocco. Anthony D'Amato

Encyclical, *ehn SIHK luh kuhl* or *ehn SY kluh kuhl,* is a letter from a Christian leader, particularly the pope, which is intended for general distribution among churches. The term originally applied to some of the letters written by Saint Paul and early church writers called Apostolic Fathers that were sent to many churches. After the time of the Apostolic Fathers, bishops wrote encyclicals to the churches in their care. In modern times, *encyclical* has come to mean a letter written by the pope to Roman Catholic churches worldwide. These letters have addressed such topics as church teachings, church discipline, current social and moral issues, peace, the rights of workers, and the plight of people living under oppression. See also **Bull.** Richard L. Schebera

Encyclopedia is a collection of information about people, places, events, and things. It may deal with all areas of knowledge or it may confine itself to just one area. A general encyclopedia, such as *World Book,* includes information on topics in every field of knowledge. Specialized encyclopedias provide more detailed and technical information on specific areas of knowledge, such as art, medicine, or the social sciences.

In ancient times, scholars found that the information they needed was scattered in manuscripts and scrolls in various parts of the world. Some scholars made their own reference works by copying long quotations from the works of other authors. Others copied items of information from a variety of sources. These ancient reference works were the ancestors of the encyclopedia. But they differ from encyclopedias in many ways. Early scholars presented information in any order they chose, and they had few ways to check its accuracy. In addition, they wrote only for themselves or other scholars. Encyclopedia editors, on the other hand, carefully organize their material and demand accuracy. They also present information to a large, diverse audience.

The word *encyclopedia* comes from the Greek words *enkyklios paideia,* meaning *general* or *well-rounded education.* The word did not come into common use until the 1700's.

A well-planned general encyclopedia presents facts about humanity; about beliefs, ideas, and achievements; about the world people live in; and about the universe of which they are a part. It presents these facts without prejudice, using language that is easy to understand.

An encyclopedia is concerned with the *who, what, when, where, how,* and *why* of things. For example, an article on radar tells *what* radar is and *who* developed it, as well as *when* and *where.* It also describes *how* radar operates and *why* it is important in everyday life.

No one person can create a general encyclopedia. Such an enterprise calls for the combined talents of scholars and specialists, of editors and educators, of researchers and librarians, and of artists, mapmakers, and production specialists. It also calls for a large investment of money by the publisher. To keep an encyclopedia abreast of events in all fields of knowledge, the publisher must revise it on a regular basis.

Until the mid-1980's, most general encyclopedias were only available in book form. Since then, several encyclopedias have been issued in an electronic format, in which information is presented on a video screen. For information on electronic encyclopedias, see the *History* section of this article.

How an encyclopedia is built

Much work goes into the preparation of a new encyclopedia or the revision of an already existing one. The publisher must have a clear-cut idea of the encyclopedia's aims and objectives. That is, the publisher must answer several basic questions. For example, what subjects should be included and what emphasis should they receive? Who is going to use the encyclopedia? How can the material be arranged to best serve the needs of the audience? What kinds of illustrations—and how many—should be included? What can be done to help readers locate information easily?

Aims and objectives. Before the editors decide on what subjects to include, they must know the general purpose that the encyclopedia will serve. The development of the subject matter also depends on whether the encyclopedia covers one or many areas of knowledge.

The audience plays a vital role in planning an encyclopedia. Some encyclopedias are planned primarily for children. Others are designed for scholars and specialists. Still others are family encyclopedias. Family encyclopedias aim to meet the reference and study needs of students in elementary school, junior high school, high school, and beyond. They are also designed as everyday reference tools for the entire family, for teachers, for librarians, and for other professional men and women.

The function of the encyclopedia editor is to provide the reader with information, accurately and objectively, so that it can be readily understood. Editors bridge the gap between what there is to know and the reader who wants to know. They serve as interpreters and translators who present information so that the reader can easily understand it.

Scope of the encyclopedia. The number of pages and the number of volumes in an encyclopedia depend on the content to be covered, who will use it, and the price for which it will be sold. Regardless of the number of volumes and pages, no encyclopedia has ever contained all the information available on every subject. Most encyclopedias include lists of books to read and other materials to consult for additional information.

Arrangement of content. Most encyclopedias use one of two basic methods of subject arrangement. These are the *alphabetical* arrangement and the *topical* arrangement.

Most encyclopedias, whether they consist of one volume or more than one, are arranged alphabetically. They may have a single alphabetical arrangement from A through Z. Or they may also have a second alphabetical listing—that is, an *index.* The index may be in a single volume, or it may be divided into segments at the ends of the other volumes.

An encyclopedia arranged on a topical basis presents its content along areas of interest. For example, one volume may be devoted to plants, another to animals, and another to history, the arts, or some other subject.

How does the publisher decide what should be put in each volume? The next time you are in a library, look at the different encyclopedias on the shelves. Some have books that are all the same thickness. Others have volumes that vary in thickness. If all the volumes have the same thickness, articles that start with some letters of the alphabet are almost certain to be split among two or more volumes. In this case, each volume must be marked in some way to show what part of the alphabet it contains—usually by showing the titles of the first and last articles in it. The first volume may be marked *A* to *Bib,* the second *Biboa* to *Coleman,* and so on. Such an arrangement is called the *split-letter* system.

Encyclopedias that use the *unit-letter* system have subjects beginning with the same letter of the alphabet in the same volume. In some cases, two or more consecutive letters of the alphabet may be combined into a single volume. A single volume may not be large enough to hold all the articles that start with the same letter, such as C, M, P, or S. In such cases, articles starting with the same letter may be split between two volumes.

Illustrations are invaluable to the process of learning and informing. Important visual aids include pictures and diagrams. Their educational and informative value depends on the creative flair and ingenuity of editors and artists working together. The illustrations should complement and supplement the information that is given in the text.

Maps are also an essential feature of a good encyclopedia. Accurate, easy-to-use maps supplement the text. They present important information that can be provided in no other way. Like other illustrations, maps should lie as close as possible to the related text.

The use of color has become increasingly important in illustrating an encyclopedia. Modern printing presses enable editors to place color illustrations throughout the set, wherever color is desirable.

Ease of use is important to every person who wants to look up information in an encyclopedia. Young readers with little experience in using reference works may prefer a single alphabetical arrangement. But they quickly learn the value of an index in finding items of information. The editors must exercise great care in se-

lecting article titles. For example, John Chapman and Johnny Appleseed are the same person, but no encyclopedia has room for two separate articles on him. The editors must choose one place for the article and put an *entry cross-reference* at the other.

Most encyclopedias use two other kinds of cross-references. One kind occurs within an article. It tells the reader that the subject just mentioned is covered under some other title in the encyclopedia. The other kind appears at the end of an article. It tells readers that the encyclopedia has articles related to the one consulted.

Indexing provides access to detailed information and draws together subjects that have significant relationships. But indexes and cross-references do the reader little good if the articles are not well organized. Ideally, the editors should give the reader ample directions to the organization of each article by using clear headings and subheadings. These headings should form a logical outline of the subject.

Format, the physical appearance of each page, can make the encyclopedia look inviting and interesting or cluttered and dull. Artists and designers must decide the size of the page, the size of the type, the length of each line, the amount of space between lines of type, and the number of columns.

How a *World Book* article is prepared

Encyclopedia articles vary in length according to the importance of the subject. Some articles may be only a few lines or a few paragraphs long. Others, such as the *World Book* article on **Painting**, may cover more than 60 pages. Methods used in preparing these short and long articles differ, depending on the kind and length of the article and on the policy of the publisher.

After an encyclopedia has been published, constant revision is necessary. From printing to printing, the editors must add new articles and revise existing ones to keep the encyclopedia up to date.

In preparing new or completely revised articles for *World Book,* the editors follow a careful step-by-step procedure. This procedure ensures that the material meets the aims and objectives of the encyclopedia. The editorial staff decides on the revisions to be made in each edition. Vital information on the changing reference needs of the audience comes from recommendations by advisers and consultants. The editors also review information from continual research into the curriculum and classroom use of *World Book.* Each new or completely revised major article passes through the following steps.

Preparing specifications. *World Book* editors prepare *specifications* (a detailed outline) for each article. The "specs," as *World Book* editors call them, tell the contributor what the article should include and, in general, how it should be developed. Before preparing specifications, an editor studies the subject thoroughly to learn what information will be of the greatest value to the audience. The editor also determines the grade or grades at which the material is likely to be used. All this information helps determine not only the content of the article, but also its vocabulary and sentence structure.

In preparing specifications, *World Book* editors use (1) a unique continuing analysis of school courses of study and (2) information gained from an extensive classroom research program. Advisers and consultants work with the editors in developing specifications.

Selecting a contributor is vital to the *World Book* editorial process. The editors select contributors who are experts in their field. For long, complex articles, such as those on states of the United States and provinces of Canada, several contributors may be used. Each expert writes about his or her area of specialization. The contributor gets a copy of the specifications, and may suggest changes for improvement.

Editing the manuscript sent in by the contributor calls for expert skill. An editor reads the manuscript to get a general grasp of what has been written. The editor then changes it, as necessary, to conform to *World Book* policies in matters of content, style, and punctuation. A researcher assists the editor in checking the facts and information. The editor clarifies any difficult concepts and adds any further facts that may be needed. The manuscript is then checked by copy editors, educators, and readability consultants. The text is stored in a computer, where it can be revised easily. After all changes have been made, a copy of the article is returned to the contributor for final approval.

Illustrating the article calls for the skills of artists and layout experts. They work closely with the editor in selecting photographs and in planning artwork for the article. Together, the text and illustrations tell the story. The layout expert places the illustrations near the text they are designed to complement and supplement.

Providing cross-references to text and illustrations is the work of specially trained editors who direct readers to specific facts or articles. Information that might otherwise be missed is thus made easy to find. The cross-reference editors also check the lists of related articles at the end of new or revised articles.

Indexing requires the skills of trained indexers and computer specialists. The indexers select items to add to the index and put them into the computer system. The computer has two files—one in the page-by-page order in which the items were selected, and the other in the alphabetical order of the final index. The index is set by high-speed photocomposition after editorial work on the rest of the encyclopedia has been completed.

Preparing for the press. Editors and designers produce *electronic pages,* which consist of text and illustrations in digital form. Files containing this information are then processed by computerized production systems that generate the final type and images. After final proofs have been approved, printing plates are made and printing and binding can begin. For more information about the mechanical aspects of making encyclopedias and other books, see **Printing** and its list of related articles.

How to judge an encyclopedia

If you plan to buy an encyclopedia, you should ask the following questions:

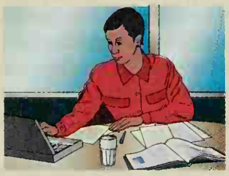
— Is it published by a reputable, experienced, and well-established company?
— Does it have a permanent editorial and art staff?
— Does it have an editorial advisory board made up of nationally known educators and scholars?
— Is it authoritative? Are the articles signed by outstanding contributors? Check the list of contributors and consultants in the first volume.

Basic steps in the preparation of a World Book article

Information presented in *World Book* articles must be accurate, authoritative, and up to date. Meeting these standards requires the help of thousands of contributors, including educators from all fields of learning, such specialists as librarians and curators of museums, and officials in business and government. Contributors work with *World Book* editors, designers, and researchers to produce articles that are accurate, interesting, informative, and easy to read.

WORLD BOOK illustrations by Jay Bensen, Jay E. Bensen and Associates

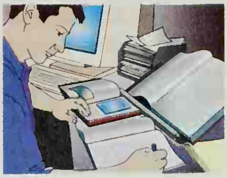
Consultants who are experts in their fields advise the editorial staff. They provide information on developments in their specialties, suggest qualified contributors, and review edited articles.



The contributor, who is an expert on the topic, writes the article. This author also reviews the edited manuscript and makes whatever changes seem necessary before giving final approval.

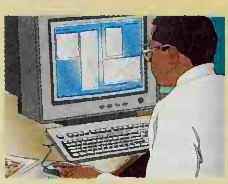
The article editor revises the contributor's manuscript to present the information in a clear, direct style. The editor gears the vocabulary to the age level of the article's most likely readers.

The copy editor polishes the edited article to make it as interesting and easy to read as possible. The copy editor also makes sure that the manuscript follows *World Book* style.



The researcher checks authoritative sources to ensure that the statistics and other information in the text are accurate and up to date.

Cross-reference editors add references to other articles in the encyclopedia to help readers find additional information on the subject. They also add references from other articles to this one.



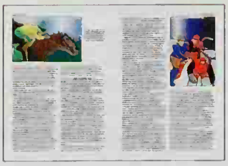
The designer, or *layout artist,* plans the layout of the article and then stores it in the computer. Later, the designer calls the text into the layout, ensuring that illustrations are placed in relation to the text.

The photo editor obtains photographs and other pictorial material to illustrate the article. Designers and editors work together to select illustrations that are both informative and easily understood.

The art director oversees the work of the designer and the photo editor. The art director also participates in the reviews of illustrations and layouts and in the selection of free-lance artists.

A free-lance artist prepares diagrams, drawings, and other artwork ordered specially for the article. The artwork is then checked for accuracy and for compatibility with the rest of the article.

The proofreader examines the copy and marks any errors with a set of symbols called *proofreaders' marks.* The editor then keys the corrections into the article.



Preparing for the press. Proofs of the text and illustrations are output from electronic files. The approved files are then transferred onto printing plates, and the article is ready to be printed.

- Is it accurate? Look up articles in fields with which you are familiar. Are the text and pictures understandable? Do they cover all important facts?
- Is it comprehensive? Does it cover subjects in all areas of knowledge?
- Is it up to date? Check articles that deal with current events, such as United States history.
- Is it written without prejudice?
- Is it written clearly and simply? Can readers, young and old, easily understand it?
- Is it well illustrated? Does it use color in illustrations for a purpose or just for decoration?
- Is it easy to use? Check the following items:
  - Does it have a single alphabetical arrangement or some other arrangement?
  - Are the volumes numbered and lettered clearly?
  - Is there a liberal use of cross-references?
  - Is there an accurate and comprehensive index?
  - Is pronunciation given for difficult words?
  - Are the article titles boldly identified?
- Do many articles have current lists of books to read?
- Does the publisher produce a yearbook that reviews the most important events of each year?
- How well are the books made? Is the paper of good quality? Is the printing clear and sharp? Is the binding sturdy, insectproof, and washable?

Before you purchase an encyclopedia, make sure that you understand its basic purpose and plan. If necessary, consult a librarian to make sure that the work is standard and modern. And, after you purchase the encyclopedia, *use it!* Put it in the place, at home or in school, where it can give maximum service.

History

The first reference works. Many scholars call the ancient Greek philosopher Aristotle the father of encyclopedists. In the 300's B.C., Aristotle made one of the first attempts to bring all existing knowledge together in a series of books. He also gave his own ideas on many subjects. Marcus Terentius Varro (116-27 B.C.), a Roman writer, made the next attempt. He wrote a nine-volume work on the arts and sciences called *Disciplinae* (disciplines). No actual copies of either Aristotle's or Varro's works exist today. Scholars know of them only from copies made at a later date. See **Aristotle**.

Pliny the Elder (A.D. 23-79), another Roman writer, wrote a set of reference books called *Historia Naturalis* (natural history). This set is the oldest reference work in existence. It contains thousands of facts, chiefly about minerals, plants, and animals. See **Pliny the Elder**.

The Chinese compiled their first encyclopedia in the early A.D. 200's, but no trace of it remains. A second encyclopedia, from the late 200's, was revised in the early 1600's. The most important early Chinese encyclopedia, compiled by the scholar Du You (also spelled Tu Yu) about 800, emphasizes the things people needed to know in order to get and hold jobs in the civil service.

Isidore, the Bishop of Seville, completed his *Etymologiarum libri XX* (20 volumes of etymologies) in 623. European scholars used this collection of facts as a source book for nearly 1,000 years. But today, scholars seldom depend on it because they cannot check its accuracy. Isidore rarely gave sources for his information.

A scholar in Baghdad, Ibn Qutaiba, compiled the first Arabic reference work. He wrote the *Kitab Uyun al-Ahkbar* (book of choice histories) in the 800's. A Persian scholar, al-Khuwarizmi, completed his *Mafatih al-Ulum* (key to the sciences) in the 990's. He separated what he considered Arab knowledge, including such fields as grammar and poetry, from "foreign" knowledge of such fields as alchemy and logic. The Brethren of Purity, a group of scholars at Al Basrah, in what is now Iraq, during the late 900's, produced an encyclopedia that tried to reconcile Greek and Arabic learning.

From the 1200's to the 1600's, some original reference works appeared, but most were copies, made slowly by hand. A Dominican friar, Vincent of Beauvais, wrote the *Speculum maius* (the bigger mirror) in 1244 and revised it many times before he died in 1264. He organized his material under three headings—political history, natural history, and academic subjects. He chose his title because he wanted his work to reflect all human knowledge. Long afterward, scholars continued to use the term *speculum* (mirror) for a reference work.

Bartholomew de Glanville, a theology teacher in Paris during the 1200's, wrote *De proprietatibus rerum* (on the properties of things). This work stressed the religious and moral aspects of each topic. Bartholomew wrote in Latin, but his work was soon translated into English, French, and other languages.

In China, the scholar Ma Duanlin completed the huge *Wenxian Tongkao* (general study of the literary remains) in 348 volumes in 1273. It was published in 1319. Another scholar, Wang Yinglin, completed a slightly smaller work, the *Yuhai* (sea of jade), in 1267. It was published in 1351.

During the late 1400's, following the European development of movable type for printing, copies and translations of written works became easier to produce than ever before. About 1481, the English printer William Caxton published *The Mirror of the World,* one of the first reference works in English (see **Caxton, William**). It was one of many translations of a French work, *Mappe Monde* (the image of the world).

Johann Heinrich Alsted, a German Protestant theologian, published one of the last reference works written in Latin. His *Encyclopaedia septem tomis distincta* (encyclopedia in seven volumes), issued in 1630, stressed geography.

An age of experiment in encyclopedias began in 1704 with the publication of the German *Reales Staatsund Zeitungs-Lexikon* (dictionary of government and news). This work was written by a German author, Sinold von Schütz, with a preface written by the scholar Johann Hübner. Schütz later changed its title to include the term *Konversations-Lexikon* (dictionary of conversation). This term has been used in the titles of most German encyclopedias ever since. The work, usually called simply *Hübner,* established the pattern for many later encyclopedias—all short articles, entirely the work of many contributors, with numerous cross-references.

Also in 1704, an English theologian named John Harris published his *Lexicon Technicum.* This reference work was the first that presented all articles alphabetically, used articles contributed by specialists, and included bibliographies. Ephraim Chambers, an English mapmaker, published his *Cyclopaedia, or the Universal Dictionary of Arts and Sciences,* in 1728. He based his work

on Harris's but added elaborate cross-references to simplify the search for information.

Chambers's work greatly influenced two French authors, Denis Diderot and Jean d'Alembert. They founded their *Encyclopédie ou Dictionnaire raisonné des sciences, des arts et des métiers (Encyclopedia or Systematic Dictionary of the Sciences, the Arts, and the Professions)* in 1751. The work was published in 28 volumes between 1751 and 1772. Seven more volumes were added between 1776 and 1780.

Diderot and other French writers of his time were called *encyclopedists* because of their work. The *Encyclopédie* contains a number of their revolutionary opinions. Many historians believe it contributed to the movement that led to the French Revolution (1789-1799). See **Diderot, Denis.**

The *Encyclopédie* inspired a group of British scholars, who began publishing the *Encyclopaedia Britannica* in 1768. The first edition was completed in 100 installments by 1771. A second edition, which included biographies, appeared between 1778 and 1783. The *Britannica* established a form that has been followed by many encyclopedias—all extensive articles, some of them more than 100 pages long, on broad topics.

Today's encyclopedias may consist entirely of long articles or short articles, or they may contain both. They may appear in one volume or in many volumes. Most encyclopedias are alphabetically arranged.

In France, Pierre Larousse, a former teacher, began to publish *Le Grand Dictionnaire Universel du XIXᵉ siècle (The Great Universal Dictionary of the 19th Century)* in Paris in 1865. His firm brought out *Larousse du XXᵉ siècle* in 1928. *La Grande Encyclopédie* was published in 31 volumes from 1886 to 1902. It was reissued in the 1970's. The *Grand Dictionnaire Encyclopédique Larousse* was published in 1982.

In Germany, Friedrich Arnold Brockhaus, a bookseller, completed his *Konversations-Lexikon* in 1809. It was published in many editions and translations. The latest edition is called *Brockhaus Enzyklopädie.* Josef Meyer published a major *Konversations-Lexikon* in the 1840's. This work became identified with Nazi propaganda during World War II (1939-1945) and was discontinued. It reappeared in the 1950's and has been revised several times since then. The Herder *Konversations-Lexikon,* first published from 1854 to 1857, is now known as *Der Neue Herder (The New Herder).*

Other encyclopedias include the Italian *Enciclopedia italiana di scienze, lettere ed arti;* the Russian *Bolshaya Sovetskaya Entsiklopediya;* the Spanish *Enciclopedia universal ilustrada europeo-americana* (usually called *Espasa*); the Swedish *Svensk uppslagsbok;* the Swiss *Schweizer-Lexikon;* and the Japanese *Heibonsha Dai-Hyakka Jiten.*

In Canada, the *Encyclopedia of Canada* was published in six volumes between 1935 and 1938. The 10-volume *Encyclopedia Canadiana,* which dealt only with subjects of special interest to Canadian readers, appeared in 1958. The first edition of *The Canadian Encyclopedia,* published as a three-volume set, appeared in 1985. *The Junior Encyclopedia of Canada,* made for children, appeared in 1990.

In the United States, printers made illegal copies of the *Encyclopaedia Britannica* as early as 1798. The first edition of *Encyclopedia Americana* appeared in 13 volumes from 1829 to 1833. Francis Lieber, a German American editor, translated much of it from the seventh edition of Brockhaus's *Konversations-Lexikon.* A firm in the United States bought *Encyclopaedia Britannica* in the 1920's.

In 1911, Americans published the first one-volume encyclopedia, *The Volume Library.* It was followed by the *Lincoln Library of Essential Information* in 1924. The one-volume *Columbia Encyclopedia* appeared in 1935. *The New Columbia Encyclopedia* came out in 1975. The one-volume *Random House Encyclopedia* was published in 1977. The first edition of *Academic American Encyclopedia* (later also published under the title *Grolier Academic Encyclopedia*) appeared in 1980. Publication of the nine-volume *Oxford Illustrated Encyclopedia* was completed in 1993.

Electronic encyclopedias first appeared in the mid-1980's and became especially popular in the 1990's. One type of electronic encyclopedia, the *CD-ROM* (*C*ompact *D*isc *R*ead-*O*nly *M*emory) *encyclopedia,* can store the same amount of information found in a multivolume set of encyclopedias on a single compact disc. Information is accessed by using a computer that has an internal or attached CD-ROM drive. CD-ROM encyclopedias called *multimedia encyclopedias* provide video, sound, and

Important encyclopedia dates

1244	Vincent of Beauvais arranged information by topics in his *Speculum maius (The Bigger Mirror).*
1410	Domenico Bandini used many cross-references in *Fons memorabilium universi (Source of Memorable Facts of the Universe).*
1506	Raffaeli Maffei included biographies in *Comentarii Urbani (Urban Commentaries).*
1541	Ringelberg of Basel was the first to use the word *cyclopedia* in the title of a reference work.
1704	The *Reales Staats-und Zeitungs-Lexikon* was the first encyclopedia to be made up entirely of the work of many contributors.
1732	Johann Zedler, in his *Universal Lexikon,* was the first to include biographies of living persons.
1751	The first part of Denis Diderot and Jean d'Alembert's *Encyclopédie* appeared.
1768	The first part of *Encyclopaedia Britannica* appeared.
1829	The first part of *Encyclopedia Americana* appeared.
1865	Pierre Larousse began *Le Grand Dictionnaire.*
1908	The British *Children's Encyclopaedia* appeared.
1910	An American version of the *Children's Encyclopaedia* appeared as *The Book of Knowledge.*
1917	The first edition of *World Book* was published.
1922	The first edition of *Compton's Pictured Encyclopedia* appeared.
1935	The one-volume *Columbia Encyclopedia* appeared.
1948	*The Oxford Junior Encyclopaedia* was published.
1949	The first edition of *Collier's Encyclopedia* appeared.
1966	*The New Book of Knowledge* was published.
1967	*Merit Students Encyclopedia* appeared.
1974	A restructured *Encyclopaedia Britannica* appeared.
1977	The one-volume *Random House Encyclopedia* appeared.
1980	The first edition of *Academic American Encyclopedia* (later also published as *Grolier Academic Encyclopedia*) appeared.
1986	*The Electronic Encyclopedia,* the first CD-ROM encyclopedia, appeared. It was a compact disc version of *Academic American Encyclopedia.*
1990's	Multimedia and online encyclopedias, including *World Book,* became popular.

motion in addition to illustrations and text.

Online electronic encyclopedias became increasingly popular in the late 1990's and early 2000's. Online searching involves using a *modem* or other device to link a computer to a network in order to access information stored on electronic databases at other locations.

In the early 2000's, most encyclopedias were updated and maintained only in their electronic formats. However, *World Book* continued to carry out extensive revisions of its print encyclopedia, as well as its CD-ROM and online versions. Other leading electronic encyclopedias included variations of *Encyclopedia Americana, Encyclopaedia Britannica, Compton's Interactive, Grolier Multimedia,* and *Microsoft Encarta.*

World Book was first published in 1917 in 8 volumes. It grew to 10 volumes in 1918. The editors began a system of continuous revision in 1918 and a yearly revision program in 1933. They began to use analyses of contents of courses of study in 1936 and of classroom use of reference works in 1955. The set grew to 13 volumes in 1929, to 19 in 1933, and to 20 in 1960. The set expanded to 22 volumes in 1971, when an index was added.

In 1961, *World Book* became the first encyclopedia published in braille. In 1964, *World Book* was published in a large-type edition for people with visual problems. In 1980, *World Book* became the first encyclopedia reproduced as a voice recording.

In 1990, World Book produced *The World Book Information Finder.* This CD-ROM product featured the text and 1,700 tables from *The World Book Encyclopedia* and 225,000 dictionary entries from *The World Book Dictionary. The World Book New Illustrated Information Finder,* introduced in 1994, also included pictures and maps.

The World Book Multimedia Encyclopedia, which was introduced in 1995, added animation, videos, and audio. In 1997, World Book and International Business Machines Corporation (IBM) combined their resources to produce a major revision and enhancement of the CD-ROM version of *World Book.* This electronic reference work contained hours of multimedia technologies, including videos, animations, simulations, virtual realities, audio, pictures, and maps. *World Book Online,* an online version of *World Book,* became available to schools and libraries on a subscription basis in 1998 and to individual and home subscribers in 1999.

Also in 1999, World Book launched a 13-volume general reference, *The World Book Student Discovery Encyclopedia.* Written at a lower reading level than *World Book,* it provided a bridge to *World Book* for students of all ages, especially young readers. Dale W. Jacobs

Related articles in *World Book* include:

Bacon, Roger	Index
Cross-reference	Reading
Electronics (picture: Electronic encyclopedia)	Study
	Vocabulary

Additional resources

"Encyclopedia Update." In *Booklist,* published annually. An American Library Association editorial board summarizes the arrangement, content, style, and general quality of major print and electronic encyclopedias.

Kister, Kenneth F. *Kister's Best Encyclopedias: A Comparative Guide to General and Specialized Encyclopedias.* 2nd ed. Oryx, 1994.

Whiteley, Sandy, ed. *Purchasing an Encyclopedia: 12 Points to Consider.* 5th ed. Am. Lib. Assn., 1996.

Endangered species are living things threatened with *extinction*—that is, the dying off of all of their kind. Thousands of species of animals and plants are endangered, and the number increases each year. Some examples of endangered species are blue whales, giant pandas, orangutans, rhinoceroses, sea turtles, snow leopards, tigers, and whooping cranes. Among endangered plants are running buffalo clover, Santa Cruz cypress, snakeroot, and many species of cactuses.

Each species of plant and animal plays a part in the delicate balance of its *ecosystem,* its relation to other living things and to the environment. Thus, the extinction of large numbers of species threatens the survival of other living things, including human beings. As more species have become endangered, ecosystems have become unstable or collapsed. Fortunately, people have increased their efforts to protect endangered species. See **Wildlife conservation** (Values of wildlife conservation).

Most biologists consider a species endangered if they expect it would die off completely in less than 20 years if no special efforts were made to protect it, or if the rate of decline far exceeds the rate of increase. Until the last few centuries, species became rare or died out as a result of natural causes. These causes included changes in climate, catastrophic movements in the earth's crust, and volcanic eruptions.

Today, species become endangered primarily because of human activities. Species mainly become endangered because of (1) loss of habitat, (2) wildlife trade, (3) overhunting, and (4) competition with domestic and nonnative animals.

Loss of habitat poses the greatest threat to the survival of wild species. Most animals and plants are specially adapted to live and reproduce in a specific environment or habitat and cannot survive when it is destroyed. The destruction of virgin forests by loggers and settlers and the conversion of natural grasslands into pasture for livestock have eliminated vast expanses of wildlife habitats. Marshlands have been drained for farmland and building projects. Coral reefs and many marine environments have become polluted, overfished, and even dynamited to obtain tropical fish and corals. Tropical rain forests contain the greatest variety of animal and plant life on Earth, and they are being destroyed more rapidly than any other type of wild habitat.

Wildlife trade involves the capture of animals for pets, zoo specimens, and research subjects, and the killing of animals for their fur or other body parts. The capture of wild animals for commercial use has endangered many species. For example, the Spix's macaw, a parrot of Brazil, is nearly extinct in the wild because so many have been captured for private bird collectors. Many primates, including the orangutan, have become endangered by the illegal killing of the mothers to capture their babies for zoos and pet dealers. Gorillas, chimpanzees, and other primates are killed for their meat, which is sold in African markets.

Other animals have been killed in such large numbers for their fur, hides, tusks, or horns that they are nearly extinct. Rhinoceroses, wild chinchillas, the Tibetan antelope, and snow leopards are among these. Although such animals are now protected by law in the countries where they live, they are still *poached* (hunted illegally).

Poaching also has seriously reduced the number of African elephants. See **Elephant** (Protecting elephants).

Overhunting has brought numerous species to the brink of extinction. The Caribbean manatee, the Asiatic lion, the dugong, and many species of pheasants have become endangered because people have hunted them for food and trophies.

Many species are killed by people who believe that the animals threaten their livelihoods. Livestock owners, for example, may shoot, trap, or poison wild animals that they consider a danger to their herds. Farmers and ranchers in North America have nearly eliminated the red wolf and many species of prairie dogs, while herders in Africa have almost wiped out the Simian Wolf. Some people in the fishing industry blame seals, which eat fish, for reductions in their catch. Fishing crews have killed so many Mediterranean monk seals that fewer than 200 survive.

Competition with domestic and nonnative animals is a major threat to numerous plants and animals. On many islands, native birds, mammals, and reptiles have become endangered after people introduced domestic animals. Livestock overgraze vegetation, eliminating habitat. Domestic cats prey on birds and small mammals. Rats escape from ships and infest islands, killing small birds and their eggs. In mainland areas, stocking of game fish threatens native fish, and nonnative plants and animals crowd out many native species.

Protecting endangered species. Laws and conservation programs are helping to reduce endangerment worldwide. In the United States, the Endangered Species Act of 1973 protects endangered and threatened wildlife and plants from hunting, collecting, and other activities that harm them or their habitats. Since this law was enacted, the numbers of certain endangered animals, such as the alligator, bald eagle, and peregrine falcon, have increased so much that they have been removed from the endangered list or reclassified from endangered to threatened status.

Many wild species are protected by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). This treaty, drawn up in 1973, aims to control trade in wild animals and plants, their parts, and products derived from them. Over 150 countries have joined the treaty. CITES bans trade in rhinoceros horn, cheetah fur, sea turtle shells and meat, and certain whale products. Elephant ivory was banned in 1989, but a 1997 decision enabled the African nations of Botswana, Namibia, and Zimbabwe to export a limited amount of stockpiled ivory to Japan. The ivory from

Some endangered species of animals and plants

Common name	Scientific name	Distribution	Survival problems
Animals			
American crocodile	*Crocodylus acutus*	Florida, Mexico, Central and South America, Caribbean islands	Overhunted for its hide; habitat destruction
Atlantic (or Kemp's) ridley sea turtle	*Lepidochelys kempii*	Tropical and temperate parts of the Atlantic	Overhunted for its leather; overcollection of eggs
Black-footed ferret	*Mustela nigripes*	Wyoming	Poisoning of prairie dogs, its chief prey
Black rhinoceros	*Diceros bicornis*	South of Sahara in Africa	Habitat destruction; overhunted for its horn
Blue whale	*Balaenoptera musculus*	All oceans	Overhunted for blubber, food, and whale oil
California condor	*Gymnogyps californianus*	Southern California, Arizona	Habitat destruction; hunted for sport; poisoned from lead shot and predator-control programs
Cheetah	*Acinonyx jubatus*	Africa, Iran	Habitat destruction; overhunted for sport and fur
Devils Hole pupfish	*Cyprinodon diabolis*	Nevada	Habitat destruction
Giant panda	*Ailuropoda melanoleuca*	China	Habitat destruction; illegal killing for fur; illegal capture for zoos
Imperial parrot	*Amazona imperialis*	West Indies, Dominica	Habitat destruction; illegal capture for pets
Indian elephant	*Elephas maximusk*	South-central and southeast Asia	Habitat destruction; illegal killing for ivory
Orangutan	*Pongo pygmaeus*	Borneo, Sumatra	Habitat destruction; illegal killing of mothers to obtain young for zoos and for pets
Red wolf	*Canis rufus*	Southeastern United States	Habitat destruction; killed in predator-control programs
Snow leopard	*Panthera uncia*	Central Asia	Overhunted for its fur; killed in predator-control programs
Tiger	*Panthera tigris*	Southern Asia, China, eastern Russia	Habitat destruction; illegal killing for sport and body parts
Plants			
Floating sorrel	*Oxalis natans*	South Africa	Habitat destruction
Green pitcher plant	*Sarracenia oreophila*	Alabama, Georgia	Overcollection; habitat destruction
Knowlton cactus	*Pediocactus knowltonii*	New Mexico, Colorado	Habitat destruction; overcollection
Running buffalo clover	*Trifolium stoloniferum*	Central United States	Unknown
Snakeroot	*Eryngium cuneifolium*	Florida	Habitat destruction

Endangered species

Some of the earth's most marvelous living things are endangered species. These photographs suggest the variety of species that are in danger of extinction. The greatest threat to endangered plants and animals is the destruction of their natural habitat by people. Many countries have established laws and conservation programs to protect endangered species and their habitats.

Richard Shiell, Animals Animals

El Segundo blue butterfly

Peggy Olwell, The Center for Plant Conservation

Knowlton cactus

Allison Leete, Los Angeles Zoo

California condor

Zig Leszczynski, Animals Animals

Tiger

Peter Weimann, Animals Animals

American crocodile

W. K. Fletcher, Photo Researchers

Sockeye salmon

these three nations was auctioned to Japanese buyers in 1999.

Various organizations publish lists of endangered species to improve public awareness. The IUCN (International Union for the Conservation of Nature and Natural Resources) compiles lists that include thousands of animal and plant species that are threatened or endangered.

Protecting habitat is the key method of preserving endangered species. Many governments and organizations have set aside nature preserves. Some zoos and animal research centers conduct programs that breed endangered species in hopes of returning their offspring to the wild. The programs have greatly improved the outlook for such endangered species as the black-footed ferret and the California condor. Greta Nilsson

Related articles. *World Book* has separate articles on many of the plants and animals mentioned in this article. See also:

Animal (The future of animals)
Biodiversity
Bird (Endangered species)
Coral reef
Extinct animal
Poaching
Wildlife conservation

Endecott, John (1588?-1665), also spelled Endicott, was an American colonial official who led about 50 people from England to what is now Salem, Massachusetts, in 1628. He governed Salem until John Winthrop

arrived in 1630. Endecott remained a leader in Salem, while Winthrop established Boston. See **Winthrop, John.**

Endecott served as governor of Massachusetts Bay Colony for several terms. His zeal often led him astray. Endecott was largely responsible for causing the Pequot War (see **Indian wars** [The Pequot War]). He slashed the red cross out of the British flag because he thought it was a symbol of the pope. Endecott persecuted the Quakers. But he used the colony's ministers to bring harmony to the community. Endecott was born in Devonshire, England. John W. Ifkovic

Enderby Land, *EHN duhr bee,* is a region on the fringe of Antarctica. The region extends from Ice Bay to Edward VIII Bay. For location, see **Antarctica** (map). Enderby Land was discovered in 1831 by British navigator John Biscoe, who worked for a whaling company called Enderby Brothers. Ian W. D. Dalziel

Enders, John Franklin (1897-1985), a research bacteriologist, shared the 1954 Nobel Prize in physiology or medicine with Frederick C. Robbins and Thomas H. Weller. The three grew poliomyelitis viruses on living human embryonic tissue and neutralized the viruses' cell-changing action with an antibody. They later isolated and typed the three strains of poliovirus (see **Poliomyelitis**).

Enders's work showed that viruses can be grown outside the body in tissues that they do not usually attack within the body. This work provided a method for producing vaccines to combat the viruses.

In 1930, Enders helped develop typhus vaccine. He also isolated the measles virus and developed a "live" measles virus vaccine (see **Measles**). Enders was born on Feb. 11, 1897, in West Hartford, Connecticut.

Kenneth R. Manning

Endive, *EHN dyv* or *AHN deev,* is a leafy vegetable closely related to chicory. It grows wild in the East Indies but is cultivated in other parts of the world. Endive grows close to the ground. One variety, known as *escarole,* has broad, smooth leaves. The other variety has curled or fringed leaves. Both of these plants have a slightly bitter, but pleasant, flavor and are often used in salads. Endive plants do not grow well in hot weather. Methods of cultivation are similar to those used for growing lettuce. Endive contains vitamins A, B, and C.

Hugh C. Price

Scientific classification. Endive belongs to the composite family, Compositae. It is *Cichorium endivia.*

WORLD BOOK illustration by John D. Dawson

Endive is a leafy vegetable often used in salads. The two varieties of endive, *curly endive* and *escarole,* are shown here. Curly endive has curled or fringed leaves, and escarole has broad, smooth leaves. Both have a bitter, but appealing, taste.

Endocrine gland. See Gland.

Endometriosis, *EHN doh MEE tree OH sihs,* is a disease of the female reproductive system in which clusters of cells from the lining of the uterus invade other areas of the body. The areas that are most often affected are the ovaries and the walls of the pelvic and abdominal cavities.

Endometriosis is most frequently diagnosed in women 20 through 40 years of age who have never been pregnant and who have experienced severe menstrual pain, infertility, or both. Most doctors believe endometriosis develops when some menstrual blood from the uterus flows backward into the pelvic and abdominal cavities each month. This blood contains clusters of uterine cells, which can attach to the organs, ligaments, or walls of the cavities. These endometrial clusters are stimulated to grow by *estrogen,* the hormone that stimulates the monthly growth of the uterine lining (see **Estrogen**).

Depending on the location of the clusters, endometriosis may produce such symptoms as bladder irritation, pain during intercourse, and severe cramps during menstruation. The disease can also damage the ovaries and other reproductive organs, which results in infertility (see **Infertility**).

Mild endometriosis may require no treatment. Doctors can treat some patients with hormones, which may halt the disease. More severe cases of endometriosis require surgery. In women who want to have children, the surgery is limited to removal of the endometrial clusters. In women who do not want to become pregnant or who are past childbearing age, the reproductive organs and all endometrial clusters may be removed.

Gretajo Northrop

Endorphin, *ehn DAWR fihn,* is any of a group of substances in the nervous system of human beings and animals. Endorphins, along with closely related chemicals called *enkephalins,* are part of a larger group of morphinelike compounds called *opioids.* Opioids help relieve pain and promote a feeling of well-being. Scientists believe that endorphins and enkephalins control the brain's perception of, and response to, pain and stress and may form part of the body's pain-relieving system.

Scientists have discovered several kinds of endorphins and enkephalins, all of which are *peptides* (chains of amino acids). *Beta-endorphin* is one of the most extensively studied opioid peptides. It occurs in the brain and in the pituitary gland, a small gland at the base of the brain, where it may act as a hormone. Beta-endorphin and another hormone called *adrenocorticotropin* (ACTH) are contained in larger molecules in the pituitary gland. These hormones are split and released as part of

the body's coordinated response to extreme pain or stress.

Scientists believe that opioid drugs produce some of their effects by acting like endorphins and enkephalins. Research chemists have artificially produced endorphins and enkephalins and have studied their use in the control of pain. Although these substances occur naturally in the body, they produce physical dependence when administered as a drug. James N. Campbell

Endoscope, *EHN duh skohp,* is a medical instrument used to examine the interior of a hollow organ or cavity of the body. Unlike most other medical imaging devices, endoscopes are inserted directly into the organ or cavity being examined. There are several types of endoscopes. Each type has its own name and is used for viewing a specific part of the body. For example, a *gastroscope* is used to examine the stomach; a *bronchoscope,* the upper passages of the lungs; and an *arthroscope,* the small spaces within joints.

Most endoscopes consist of a flexible or rigid hollow tube with a lens at one end. Light-transmitting threads called *optical fibers* extend along the inside of some tubes. The optical fibers shed light on the tissue and permit viewing through the lens.

Various medical procedures, including certain types of surgery, can be performed through an endoscope. For example, forceps can be passed through an endoscope to obtain samples of tissue. Lasers can be inserted through an endoscope to destroy abnormal tissue or to remove fatty deposits within blood vessels.

Charles Liebow

See also **Arthroscopy; Bronchoscope; Fiber optics** (Kinds of optical fibers); **Gastroscope.**

Evanston Hospital

University of Chicago Medical Center

Doctors use a gastroscope to examine a patient's digestive system. This type of endoscope is passed through the mouth of the patient to the stomach. The small photograph shows a stomach ulcer as seen through a gastroscope.

Endowment is a fund that is set aside by a donor, or giver, for a specific purpose. The term *endowment* also has the same meaning as foundation, fund, or trust (see **Foundations; Trust fund**). The money for endowments may come from individuals, family estates, or business organizations. Most endowments are designed to run forever, or until all the money in the fund has been spent. Many endowments are nonprofit, tax-exempt organizations that finance numerous social welfare projects.

Endowments also refer to funds that are held by colleges, universities, hospitals, orphanages, and other institutions. The money is usually invested so that the institution has a continual income of some kind. Usually, the institution spends only the income or profit from the investments. In this way, the endowment can continue forever. Generally, the income from the endowment is used only for the general operations of the institution, or for some particular purpose for which the endowment was created. Joseph C. Kiger

Endymion, *ehn DIHM ee uhn,* in Greek mythology, was a handsome youth passionately loved by Selene (the moon). Details of Endymion's life vary from author to author in ancient Greece. According to one story, Selene put Endymion to sleep forever because she could not bear to have him die. In another version, Selene begged Zeus, the ruler of the gods, to grant Endymion a wish. He chose everlasting sleep combined with eternal youth and immortality.

The story of Endymion and Selene has inspired many artists and writers. For example, the English poet John Keats wrote *Endymion* (1818), a long poem based on the Greek myth. F. Carter Philips

See also **Selene; Keats, John** (His work).

Energy, in physics, is a quantity that is related to work. Energy has many forms. For example, you use *mechanical energy* when you toss a ball, *heat energy* warms a room, *electric energy* makes a light bulb glow, and *chemical energy* provides the driving force for an automobile.

Solar energy, energy from the sun, warms and illuminates Earth and its atmosphere. Almost all that energy arrives at the top of the atmosphere as electromagnetic waves. From the least energetic to the most energetic, those waves include radio waves; infrared rays, which we feel as heat; visible light; ultraviolet rays, which can cause sunburn; and small amounts of X rays and gamma rays. The atmosphere blocks some of the visible light and infrared rays, almost all of the radio waves and ultraviolet rays, and all of the X rays and gamma rays. The term *solar energy* also refers to energy supplied by solar panels and other devices that use energy from the sun.

Two forms of energy are fundamental—that is, any other form consists of one or both of them. The two forms are: (1) *kinetic energy,* which is energy of motion; and (2) *potential energy,* which can be thought of as "stored" energy. For instance, the mechanical energy involved in picking up and dropping a ball is partly potential energy and partly kinetic energy. Pick up the ball,

and you give it potential energy. Drop the ball, and the potential energy of the ball is transformed into kinetic energy.

Energy conversion

Energy can be converted from one form to another. For example, our bodies change chemical energy in food to mechanical energy that we use when we move about. A coal-burning power plant converts chemical energy to electric energy.

Energy conversion at a power plant occurs in several stages. The following description of that process may help you understand various forms of energy and how they can be converted.

The coal has potential energy in the form of chemical energy. That chemical energy is stored in the electrons of atoms that make up the molecules in the coal. Each atom consists of one or more negatively charged electrons in orbit around a positive nucleus. Electrons in neighboring atoms form pairs that *bond* (join) the atoms together.

When the coal burns, its molecules change as bonds break and other bonds form. As the molecules change, electrons release energy, which is immediately converted to *heat energy.* Heat energy is the kinetic energy of the atoms and molecules of a solid object, a liquid, or a gas; the hotter an object, the greater the kinetic energy of its atoms and molecules.

In the power plant, the molecular changes that occur when the coal burns create hot gases. In the next stage of the process, heat energy in the gases changes to heat energy in the metal that makes up a boiler, then to heat energy in molecules of water inside the boiler. As the water molecules absorb heat energy, they move more and more rapidly. Eventually, they move so rapidly that water turns to steam.

The steam then flows from the boiler through pipes to a device known as a *steam turbine.* The turbine has several wheels, each with fanlike blades. The steam rushes through the blades, pushing against them and thereby spinning the wheels. In this stage, heat energy of the steam is converted to mechanical energy of the turbine.

The turbine is connected to a machine called an *electric generator.* In the final stage of the process, the generator converts mechanical energy of the spinning turbine to electric energy (see **Electric generator**). That energy is partly kinetic and partly potential.

Conservation of energy

In 1847, the British physicist James Prescott Joule demonstrated that mechanical energy can be converted into heat. Soon, scientists learned that any form of energy can be converted to any other form. They also found that, in energy conversions, the total quantity of energy is *conserved:* The quantity of energy that exists at the end of any process is the same as the quantity that existed when the process began.

Some of the energy at the end of every process is waste energy. For example, in an automobile, much heat energy goes out the exhaust pipe, and friction between parts of the engine creates heat energy that is wasted. But the automobile's heating system can use waste heat to warm the passengers on cold days.

Energy and matter

Almost 60 years after Joule's demonstration, the German-born American physicist Albert Einstein expanded the idea of conservation of energy. The expanded idea was an outgrowth of Einstein's special theory of relativity, published in 1905. Einstein explained that matter can be converted to energy and vice versa. The energy available from a conversion of matter is sometimes called the *energy-equivalent of mass.* Mass is the amount of matter in an object. An energy-equivalent of mass is potential energy.

The conversion of matter releases energy in the sun and other stars. The sun's core is so hot that atomic nuclei and electrons move about independently. The most common nucleus is that of the simplest form of hydrogen—a single proton. The protons have so much kinetic energy that they sometimes collide and *fuse* (join), producing a hydrogen nucleus consisting of a proton and an electrically neutral *neutron.* But the mass of that nucleus is less than the sum of the masses of a proton and a neutron when they are separate. The "missing matter" has been converted to energy.

Conversion of matter to energy also produces the heat energy that is used to generate electric energy in nuclear power plants. In addition, matter-to-energy conversion provides the tremendous destructive force of nuclear weapons.

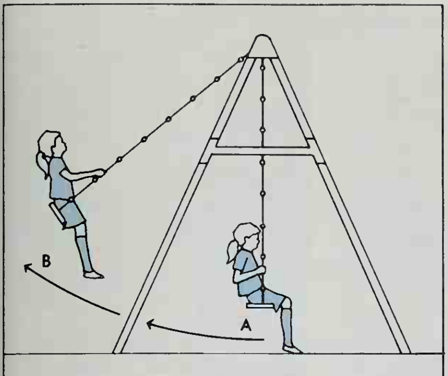
Calculating quantities of energy

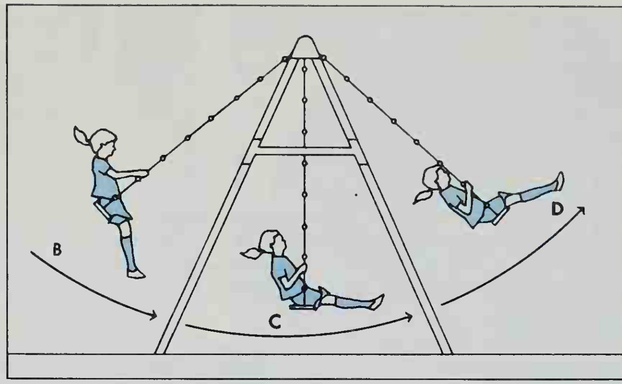
Scientists use *Newtonian equations* and *relativistic equations* to calculate quantities of energy. Newtonian equations are based on *Newton's laws of motion,* which were discovered by the English scientist Isaac Newton. The laws were published in 1687 in *Philosophiae Naturalis Principia Mathematica (Mathematical Principles of Natural Philosophy),* a work usually called simply *Principia* or *Principia Mathematica.*

Relativistic equations are based on Einstein's special theory of relativity, and they apply to realms of physics that were unknown in Newton's time. For example, scientists use a relativistic equation for the kinetic energy of an object traveling at more than a few percent of the speed of light in a vacuum, 186,282 miles (299,792 kilometers) per second. But a Newtonian equation will give an extremely accurate value of the kinetic energy of an object moving at a speed typical of objects seen in our everyday lives. The equations used in this article are Newtonian.

Units of work and energy. Due to the relationship between energy and work, energy is measured in units of work. In its scientific sense, *work* is the movement of an object against a resisting force. For example, a person does work by lifting an object. Lifting an object requires work because the lifter must overcome the force of gravity on the object. The amount of work done, and therefore the amount of energy used, equals that force multiplied by the distance the object is lifted. The kinetic energy used to lift the object is "stored" in the object as potential energy.

In the inch-pound system of units customarily used in the United States, work and energy are commonly measured in foot-pounds. In the International System of Units (SI), the modern metric system, work and energy





WORLD BOOK diagrams

A girl on a swing illustrates how *potential* (stored) energy becomes *kinetic* (moving) energy and vice versa. In the diagram at the left, the girl has maximum potential energy but no kinetic energy when she is in position B. In the diagram at the right, gravity swings her down from position B. At position C, she has no potential energy, but maximum kinetic energy, which swings her to D.

are measured in units known as *joules*—named for James Prescott Joule. One joule is equal to 0.738 foot-pound.

Another unit of energy is the *thermochemical calorie,* which is usually referred to as simply the *calorie.* This unit is not part of the SI, but scientists commonly use it in studying heat. The calorie equals exactly 4.184 joules. The thermochemical calorie is not the same calorie used in the field of nutrition. Instead, nutritionists use the *kilocalorie,* which equals 1,000 thermochemical calories. But the kilocalorie is also referred to as the *calorie,* and sometimes as the *Calorie*—with a capital "C" to distinguish it from the thermochemical calorie.

Energy and power. People sometimes confuse energy with *power.* Power is the rate at which energy is delivered—so power equals energy divided by time. In the inch-pound system, one unit of power is the *horsepower,* which equals 550 foot-pounds per second. In the SI, the unit for power is the *watt,* named for the Scottish inventor James Watt. One watt equals 1 joule per second. The watt is much smaller than the horsepower. One *kilowatt* (1,000 watts) equals 1.341 horsepower.

Weight and mass. The amount of energy used to lift an object can also defined as the weight of the object multiplied by the distance the object is lifted. In this definition, *weight* is used in its scientific and technological sense to mean the force of gravity on the object. But this usage can be confusing because, in commercial and everyday use, *weight* means *mass.*

Weight, in the scientific and technological sense, is proportional to mass. The two quantities are related by the equation $F_g = mg$, where F_g is force due to gravity (that is, weight), m is mass, and g is the acceleration that a falling object undergoes due to gravity. Scientists typically work in metric units. The metric units that apply to this equation are newtons—named for Isaac Newton—for F_g, kilograms for m, and meters per second per second for g. At Earth's surface, g is about 9.8 meters per second per second.

Suppose that you wanted to find the weight of a rock that has a mass of 2 kilograms. You would insert that value of 2 kilograms and the value of g into the equation and multiply: $F_g = (2)(9.8) = 19.6$ newtons.

Potential energy of a raised object. Suppose a person raised the rock to a height of 2 meters. What would be the potential energy of the rock?

The equation for the potential energy of a raised object is $E_p = F_g s$. E_p is energy in joules, F_g is force due to gravity in newtons, and s is the distance the object has been raised in meters. We insert the values of F_g and s into the equation and multiply: $E_p = (19.6)(2) = 39.2$ joules.

Kinetic energy. Suppose the person threw the rock at a *velocity* (speed in a particular direction) of 12 meters per second. What would be the kinetic energy of the rock?

The equation for kinetic energy is $E_k = (\frac{1}{2})mv^2$. E_k is energy in joules, m is mass in kilograms, and v is velocity in meters per second. The 2 beside the v indicates that v is to be *squared* (multiplied by itself). So the calculation is $E_k = (\frac{1}{2})(2)(12)(12) = 144$ joules.

Michael Dine

Related articles in *World Book* include:

Power
Relativity
Solar energy
Square root
Turbine
Weight
Work
Watt
Watt, James

Energy, Department of, is an executive department of the United States government that works to meet the nation's energy needs. The Department of Energy develops and coordinates national energy policies and programs.

The secretary of energy, who is a member of the president's Cabinet, directs the department. The secretary is appointed by the president, subject to the approval of the Senate.

The seal of the Department of Energy

Functions. The United States Department of Energy has four main areas of responsibility. These four areas are: (1) the development of energy resources, (2) scientific research, (3) national security, and (4) protection of the environment.

Development of energy resources. The department works to develop energy technologies that private industries are not likely to develop themselves. These technologies include certain ways of increasing the nation's energy supply and of using the current supply more efficiently.

Scientific research is conducted in national laboratories supervised by the Department of Energy. Scientists in the laboratories work to develop cleaner and more economical energy sources and to improve the competitiveness of U.S. industries.

National security. The department manages the nation's nuclear-weapons development program. It also works to maintain a safe, reliable stockpile of nuclear weapons.

Protecting the environment. The department finds ways to reduce environmental, safety, and health risks that have resulted from nuclear-weapons development and production. It also works to reduce environmental damage from the development and use of energy resources.

History. Congress created the Department of Energy in 1977. The new department pulled together energy-related functions that had been scattered throughout the government. For example, the Department of Energy took over electric power projects and coal research programs from the Department of the Interior. In addition, the new department absorbed three independent agencies—the Energy Research and Development Administration, the Federal Energy Administration, and the Federal Power Commission.

Secretaries of energy

Name	Took office	Under President
James R. Schlesinger	1977	Carter
Charles W. Duncan, Jr.	1979	Carter
James B. Edwards	1981	Reagan
Donald Paul Hodel	1982	Reagan
John S. Herrington	1985	Reagan
James D. Watkins	1989	G. H. W. Bush
*Hazel R. O'Leary	1993	Clinton
*Federico F. Peña	1997	Clinton
*Bill Richardson	1998	Clinton
Spencer Abraham	2001	G. W. Bush

*Has separate biography in *World Book.*

Critically reviewed by the Department of Energy

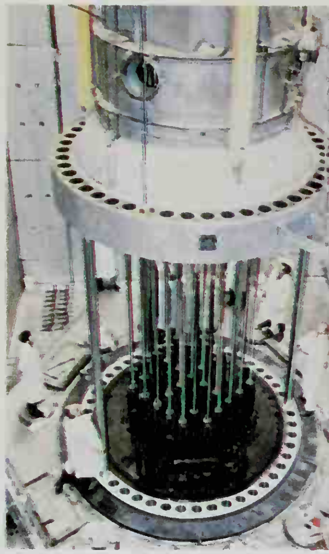
Related articles in *World Book* include:

Argonne National Laboratory
Brookhaven National Laboratory
Fermi National Accelerator Laboratory
Flag (picture: Flags of the United States government)
Idaho National Engineering and Environmental Laboratory
Lawrence Berkeley National Laboratory
Lawrence Livermore National Laboratory
Los Alamos National Laboratory
National laboratory
Oak Ridge National Laboratory
Sandia National Laboratories

U.S. Department of Energy

Department of Energy headquarters are in Washington, D.C. The department conducts research on energy production, encourages energy conservation, and manages the production of the nation's nuclear weapons.

Ron Church, Tom Stack & Assoc.



U.S. Department of Energy

Georg Gerster, Rapho Guillumette

Sources of energy include petroleum, nuclear energy, and sunlight. Offshore wells, *left,* tap oil deposits that lie underwater. Nuclear reactors, *center,* produce power from the splitting of atomic nuclei. Solar furnaces, *right,* use mirrors to collect the rays of the sun.

Energy supply

Energy supply is the total quantity of usable energy available to people for doing work. We use forms of energy to operate machinery; to heat and cool our homes and offices; to cook; to provide light; and to transport people and goods. Heat energy is the most commonly used form of energy.

Energy may be obtained directly from an energy source, as when people burn wood to produce heat. Energy also may be obtained indirectly. For example, at a power plant, oil is burned to create steam. The steam turns a generator, thus producing electric power.

Energy that is produced by businesses and governments and sold to the public is called *commercial energy.* About 85 percent of all commercial energy comes from petroleum, coal, and natural gas. These sources are called *fossil fuels* because they developed from the fossilized remains of prehistoric plants.

The earth contains only a limited supply of fossil fuels. But the amount of fossil fuel burned by people to produce energy has nearly doubled every 20 years since 1900. Someday, the supply will run out. Scientists and engineers are working to develop other sources of energy to replace the shrinking reserves of fossil fuels.

Sources of energy

The world's chief sources of energy are, in order of importance, fossil fuels, water power, and nuclear energy. Wood, solar, wind, tidal, chemical, and geothermal sources also provide energy. Future energy sources may include fuel cells, solid and liquid wastes, hydrogen, and magnetohydrodynamic (MHD) generators.

Peter J. Catania, the contributor of this article, is Professor of Engineering at the University of Regina in Saskatchewan, Canada.

Fossil fuels include, in order of the amount used worldwide, petroleum, coal, and natural gas. Bituminous sands and oil shale form important energy resources for the future.

Petroleum furnishes about 40 percent of the commercial energy used in the world and about 40 percent of that used in the United States. Most of the heat energy in petroleum is used to produce transportation fuels, such as gasoline and diesel fuel, and heating fuels.

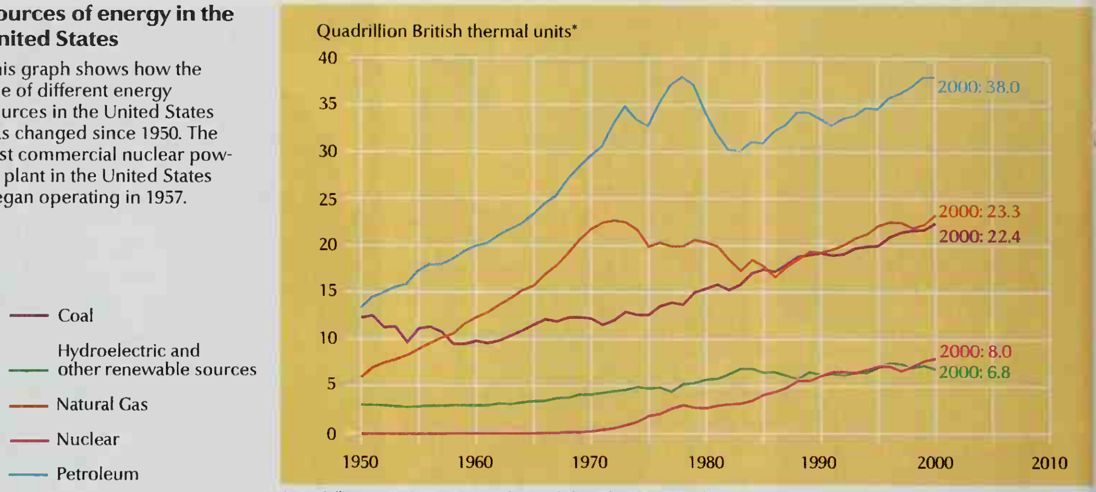
Most petroleum is removed from deep within the earth as a liquid called *crude oil.* Workers pump crude oil out of the earth through wells drilled into oil-bearing formations called *reservoirs.* Because it is a liquid, crude oil can be economically transported long distances by pipeline to refineries. Refineries process it into gasoline and other petroleum products. Refining removes many impurities that could cause pollution from crude oil.

Coal provides about 23 percent of all the commercial energy used in the world. It furnishes about 22 percent of the energy used in the United States. Much of the heat energy in coal is used to produce steam in boilers. The steam, in turn, generates electric power or operates steam engines. Coal also is used in the manufacture of steel. In many countries of Asia and Europe, people use coal to heat homes and other buildings.

The mining and burning of coal involve certain problems. Accidents in coal mines and diseases that result from breathing coal dust make coal mining a dangerous occupation. When burned, coal releases sulfur and other impurities that pollute the air. To reduce pollution, many large factories that burn coal have installed filters and other cleaning devices.

Sources of energy in the United States

This graph shows how the use of different energy sources in the United States has changed since 1950. The first commercial nuclear power plant in the United States began operating in 1957.



*1 quadrillion = 1,000,000,000,000,000. The *British thermal unit* (Btu) is used in the U.S. to measure energy. 1 Btu = 1,055 joules.
Source: U.S. Energy Information Administration.

Chemists have developed various methods of turning coal into a gas or a liquid. Gasification and liquefaction convert coal into a clean fuel that has a low sulfur content. However, such conversion is expensive and requires huge quantities of coal.

Natural gas accounts for about 23 percent of the commercial energy used in both the world and the United States. Most of the heat energy contained in natural gas is used to generate steam for electric power or steam engines, to heat buildings, and for cooking and other household needs.

Like petroleum, natural gas comes from deposits in the earth. Natural gas is a clean source of energy because it is refined naturally during its formation within the earth and does not require further refining. In addition, natural gas can be compressed into a liquid and transported long distances through pipelines.

Bituminous sands and oil shale may become energy sources in the future. Bituminous sands, also called *tar sands,* are deposits of sand covered with an oil-producing substance. Oil shale is a type of rock that can be processed to yield crude oil and natural gas. The cost of obtaining oil from tar sands and oil shale is higher than that of obtaining petroleum, coal, or natural gas directly from the earth. But as reserves of these fuels run out, it will become necessary to recover the more costly energy from tar sands and oil shale.

Water power, or *hydropower,* furnishes about 7 percent of the world's commercial energy and 3 percent of the energy used in the United States. Where water flows from a high place to a lower one, the gravitational energy of the falling water can be captured and used to produce other forms of energy. Most water power is used to generate electric power. Water power supplies energy without pollution and without using up the water in the process. But costly dams and other structures are required to harness water power.

Nuclear energy provides about 6 percent of the commercial energy used in the world and 8 percent of the energy used in the United States. Today, nuclear energy comes from *fission*—that is, the splitting of atomic nuclei of certain elements, especially uranium. But scientists hope eventually to produce nuclear energy from fusion, the combining of atomic nuclei.

Nuclear fission creates huge amounts of energy from small amounts of fuel. The heat energy that is produced during controlled fission reactions can be used to power submarines and other ships and to generate electric power.

But fission has several disadvantages as a source of energy. Fission plants produce hot waste water that may damage the environment. To reduce this *thermal pollution,* most new nuclear power plants have large, expensive cooling devices. Nuclear power plants also generate radioactive wastes that remain dangerous for long periods. These wastes must be isolated to protect the environment from radioactivity. In addition, a serious accident at a nuclear power plant can release harmful radioactivity into the air.

Scientists and engineers have developed experimental *breeder reactors.* But no breeder yet produces enough energy for commercial use.

Nuclear fusion produces the heat and light of the sun and other stars, and the explosive force of the hydrogen bomb. Scientists and engineers are working on ways to control nuclear fusion reactions. Experimental fusion devices use forms of hydrogen known as *deuterium* and *tritium* for fuel. Because hydrogen is found in large quantities in the world's oceans, fusion could provide an unlimited source of fuel. In addition, fusion devices are safer than fission devices. Fusion would not create a waste disposal problem because most products of fusion reactions are not radioactive. However, fusion devices have yet to produce usable amounts of energy.

Wood once served as the world's chief fuel. In many developing countries, wood is still the main source of heat energy. But in the United States and many other developed countries, the use of wood for heating is limited mainly to fireplaces.

Solar energy is used throughout the world to perform various small jobs. People capture this type of energy with various devices that change the sun's energy into heat or electrical energy. *Flat-plate collectors* convert solar energy into heat energy to heat water and the air inside buildings. *Solar cells,* also called *photovoltaic cells,* convert solar energy into electric energy.

Solar power can provide a clean and almost unlimited source of energy. But it is thinly distributed over a wide area and must be collected and concentrated to produce energy. In addition, darkness and bad weather interrupt the supply of sunlight.

Wind power turns windmills and propels sailboats. Private uses of the clean energy that is provided by wind occur all over the world. But wind power is commercially practical only in areas that have strong, steady winds.

Tidal energy comes from the gravitational energy of water as it flows from high tide to low tide. This energy can be captured by closing a bay with a dam. As the tide rises, the bay fills with water. At high tide, the dam is closed to hold the water in the bay. At low tide, the stored water is released through a turbine to generate electric power. The chief disadvantage of tidal power plants is that they can produce energy only during falling tides. Also, the plants can be built in few places.

Chemical energy is released during chemical reactions. The most common use of such energy is to generate electric power in batteries. Some chemical reactions are reversible. As a result, storage batteries such as those found in automobiles can be recharged.

Geothermal power is generated wherever water comes in contact with hot rocks below the earth's surface. The rocks give off heat that makes the water hot enough to turn into steam. Power companies can drill wells and pump the hot water or steam to the surface, where it can be used to generate energy. In areas where no underground water or steam exists naturally, engineers can pump water into the ground to be heated by hot rocks. The production of geothermal energy can occur only in areas where hot rocks lie near the earth's surface. Bolivia, Iceland, Italy, Japan, the Philippines, New Zealand, and the United States have developed geothermal power plants.

Fuel cells are batterylike devices in which gas or liquid fuels combine chemically to generate electric energy. For example, fuel cells in spacecraft combine hydrogen and oxygen to produce electric energy. Fuel cells convert chemical energy directly into electric energy without burning fuel or producing much waste heat. As a result, they can produce twice as much electric energy as can ordinary generators from a given amount of fuel. But fuel cells are expensive to make, and so their use is limited.

Solid and liquid wastes also can provide energy. Burning trash can produce heat energy and electric energy. Some paper and lumber mills use waste wood to fuel boilers, which generate steam for the plant.

Many cities throughout the world produce usable energy by burning trash. Burning wastes also reduces the amount of trash that must be placed in landfills. Cities also can process liquid organic wastes, such as sewage, to produce methane gas that can be used for fuel. Another process, called *bioconversion,* converts organic plant and animal wastes into useful liquid fuels, such as methanol, natural gas, and oil.

Hydrogen could someday replace both gas and oil as a fuel. It burns easily, giving off huge amounts of heat and one harmless by-product, water. Chilled to liquid form, hydrogen can be transported in pipelines and stored in tanks. Aircraft and automobiles may someday use this nonpolluting, lightweight, and efficient fuel. Hydrogen is removed from water by a process called *hydrolysis,* which involves running an electric current through the water. But the process requires enormous amounts of electric power, making hydrogen a costly energy source.

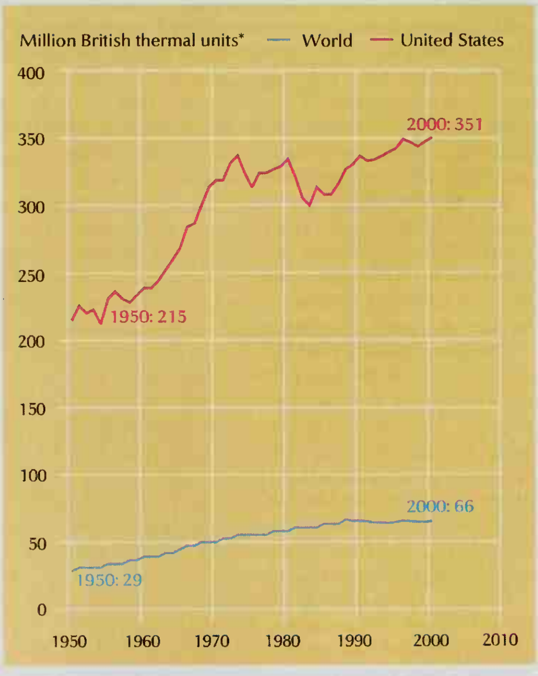
Magnetohydrodynamic (MHD) generators convert fuel directly into electric energy. An MHD generator burns coal or other fuel at high temperatures to produce hot, *ionized* (electrified) gases. These gases are forced through a duct in a magnetic field, where they produce an electric current drawn off by electrodes. After this gas passes through the generator, it can be used to drive a turbine and generate more electric power. MHD generators convert fossil fuels into electric power more efficiently than do conventional boilers and steam-driven turbines. But many technical problems must be solved before MHD generators become common.

History

Early days. Human beings learned to make fire about 1 ½ million years ago. Until then, their only sources of energy had been their own strength and direct sunlight. With the heat energy released by burning wood, people warmed themselves, cooked food, and hardened pottery. About 3200 B.C., the Egyptians invented sails and used the wind to propel their boats. Water wheels, developed in ancient times, harnessed the gravitational energy of falling water.

Energy use per person

This graph shows how energy use per person has risen since 1950. Energy use per person is about five times as high in the United States as in the entire world.



*The *British thermal unit* (Btu) is used in the U.S. to measure energy. 1 Btu = 1,055 joules.
Sources: United Nations; U.S. Energy Information Administration.

Until the late 1700's, wood ranked as the most important fuel. People used so much timber that it began to grow scarce, and coal gradually took its place as the chief fuel source. The growing demand for coal brought a search for better mining methods, including ways to keep mine shafts from flooding. In 1698, an English inventor named Thomas Savery patented an improved pump to drain mines. The pump was powered by the first practical steam engine. People now had a device that could change heat energy into mechanical energy to do work.

The Industrial Revolution. The steam engine became the chief source of power for industry and transportation during the Industrial Revolution. People's use of energy increased tremendously during this period, from the 1700's to the mid-1800's. Power-driven machinery largely replaced hand labor, and steamboats replaced sailing ships. New uses of energy made work easier and more productive, and increased production brought greater wealth. This prosperity helped bring about a growth in population, and so there were more people to consume energy. At the same time, people could afford to buy more energy-consuming conveniences.

During the 1800's, inventors learned about many new sources of energy—and ways to use this energy. In the early 1830's, two physicists—Michael Faraday of England and Joseph Henry of the United States—independently discovered a way to turn mechanical energy into electric energy. They found that a moving magnet produced electric current in a coil of wire. On this principle, which is called *electromagnetic induction,* generators could produce electric energy from the turning of a water wheel or a steam turbine.

In 1860, Jean Joseph Étienne Lenoir, a French inventor, built one of the first workable internal-combustion engines. These engines produced power from the explosion of a mixture of air and flammable vapors. Gasoline, which is made from petroleum, proved to be the most convenient fuel because it easily turned into vapor. In 1885, Karl Benz, a German engineer, built one of the first gasoline automobiles. The demand for petroleum soared as automobiles came into use.

The 1900's. During the 1900's, the use of energy almost doubled every 20 years. Causes of this growth included (1) the population increase, (2) the growth of the labor force, (3) increased wealth, (4) energy-using inventions, (5) products that take large amounts of energy to be manufactured, and (6) nonfuel uses of fossil fuels.

The population of the United States increased about 25 percent from the late 1950's to the late 1970's. But during that period, the use of energy increased about 90 percent. The standard of living improved, and people could afford to buy such energy-using conveniences as air conditioners and cars. At the same time, new appliances, including electric can openers and microwave ovens, consumed power. People also used more of such materials as aluminum and plastic, which required huge amounts of energy to manufacture.

Energy use declined in the United States during the early 1980's. A rise in natural gas and petroleum prices caused people to adopt conservation measures to save energy. These conservation measures included building more fuel-efficient cars and insulating buildings to reduce heat loss. But a decrease in fuel prices in the mid-1980's resulted in less interest in conservation and an increase in energy use.

The United States has large stocks of coal and oil. These abundant natural resources have fueled industrial expansion and helped provide one of the world's highest standards of living. Today, the United States has only about 5 percent of the world's population. But the nation consumes about 25 percent of the world's energy.

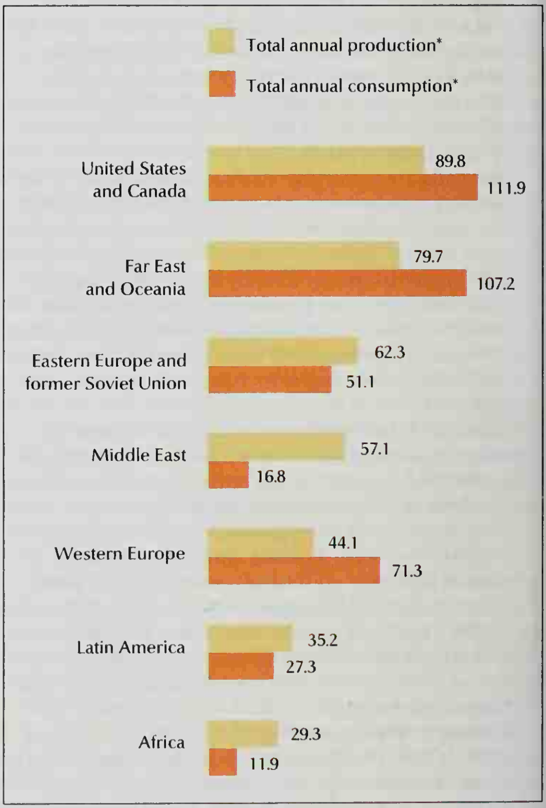
A person in a developing country uses only about a fifteenth as much energy as a person in one of the developed countries. Developing countries can do little to limit their energy consumption without sacrificing important goals. They need more factories, farm machinery, and transportation facilities, all of which require energy to operate. Their people also want more central heating, electric lighting, and other comforts that use energy.

Problems

Energy use creates serious problems. They include the depletion of fuel reserves and environmental effects.

World energy production and consumption

This graph shows the amount of commercial energy produced and used by various regions of the world. The oil-rich Middle east has the greatest surplus of energy.



*Energy in quadrillion British thermal units (Btu), the standard measure of energy in the U.S. 1 Btu = 1,055 joules. I quadrillion = 1,000,000,000,000,000.
Figures are for 2000.
Source: U.S. Energy Information Administration.

Depletion of fuel reserves. People have rapidly used up sources of energy that accumulated for millions of years. The period of greatest fossil-fuel formation began about 360 million years ago. For about 40 million years, huge quantities of dead trees and other plants were buried in the earth through natural processes. Time, heat, and pressure slowly changed this buried plant material into coal. Petroleum and natural gas were both formed in much the same way from the remains of ocean plants. The formation of fossil fuels is still going on—but people burn the fuels thousands of times faster than they form.

The rapid growth of energy use threatens to exhaust the world's supply. Petroleum may become the first fuel to give out—growing scarce by the mid-2000's. Natural gas is also being used up quickly. At present rates of consumption, natural gas may last only slightly longer than petroleum. When people have removed all the oil and natural gas from the earth, they will have used up the "easy energy" supplied by nature. After that, they will have to use such solid fuels as coal and oil shale, which are more difficult to remove from the earth. Coal, the most plentiful fossil fuel, will last more than 200 years.

As fuels become scarce, their price goes up. Many people then call for price controls on these sources of energy. But large numbers of economists believe that rising energy prices encourage energy producers to broaden their exploration and dig deeper for deposits. For example, petroleum experts might investigate ways to remove more oil and gas from each reservoir. Low-grade deposits of coal might become profitable to mine, and scientists might investigate new sources of energy. These economists also believe that higher fuel prices cause people to use energy more carefully. Nevertheless, we must eventually find new sources of energy.

Environmental effects. The production, transportation, and use of fossil fuels all affect the environment. The drilling of offshore oil fields and the shipment of petroleum by tankers sometimes result in oil spills that pollute the ocean, contaminate beaches, and kill wildlife. Burying oil pipelines requires changes in the environment, such as the clearing of trees along the route. Underground coal mines can cave in and can release dangerous gases. Strip mining has exposed large areas of land to erosion. The burning of coal and oil pollutes the air with nitrogen oxides and sulfur dioxide. These substances can react with moisture in the air and fall to earth as *acid rain,* polluting lakes and rivers. Motor-vehicle fuels rank as a leading source of air pollution. See **Acid rain; Environmental pollution.**

Even the cleanest fossil fuel produces carbon dioxide when it burns. Carbon dioxide is a harmless gas. But a build-up of this gas in the atmosphere may cause a phenomenon called the *greenhouse effect.* Carbon dioxide, like glass in a greenhouse, allows sunlight to warm the earth but prevents heat from escaping back into space. The greenhouse effect could permanently raise temperatures on the earth, partially melting the polar ice and causing floods. See **Greenhouse effect.**

Petroleum and coal companies can take various steps to reduce damage to the environment. Petroleum engineers can install protective devices to prevent the pollution of the water near offshore oil and gas wells. They can design pipelines with leak detectors to limit the extent of any leak that might occur. The coal-mining industry has worked to improve mine safety. In addition, U.S. laws require mining companies to restore mined land as closely as possible to its original state. Most large coal-burning power plants in developed countries have installed scrubbers and filters to control the pollutants that enter the air.

All other sources of energy also have environmental effects. Nuclear power plants create thermal pollution and radioactive wastes. The construction of large dams changes river conditions. Electric power lines produce electromagnetic fields that may create a health hazard. Tidal energy plants change conditions along seacoasts and may disturb marine life. Geothermal power plants release heat and gases into the atmosphere. Any use of energy, no matter how clean the source, gives off waste heat. If the use of energy continues to grow, the heat released could alter the environment of many cities.

Challenges

Challenges presented by the earth's diminishing energy supply include (1) developing new energy sources; (2) improving the efficiency of energy production, transportation, and use; and (3) conserving energy.

NASA/Science Source from Photo Researchers

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Reducing heat loss from buildings helps conserve energy. The colors in the thermogram at the far left represent the amount of heat that passes from a house during cold weather. Red and yellow indicate the areas of greatest heat loss. The installation of fiberglass insulation along walls, *near left,* controls the loss of heat and thus reduces the amount of fuel needed to heat the house.

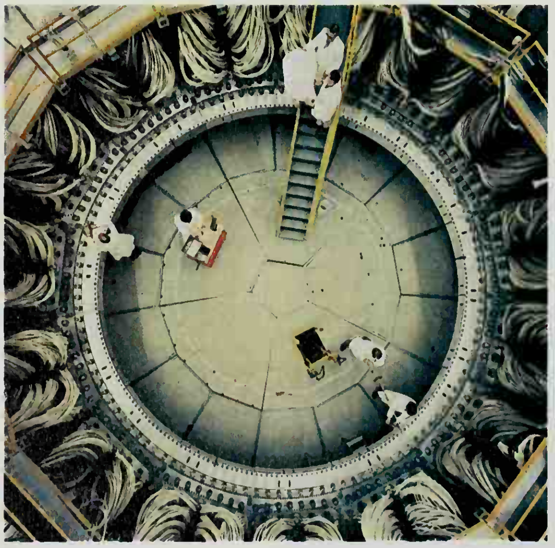
Developing new energy sources. Scientists have many problems to solve before new sources of energy become practical. Nuclear physicists have not yet produced a reliable fast breeder or controlled nuclear fusion. To turn solar energy into a practical power source, scientists must find better ways to gather, concentrate, and store it. They also must find new ways to recover the energy contained in solid and liquid wastes.

The development of a safe, clean transportation fuel to replace petroleum is a high priority in energy technology. Hydrogen could replace fossil fuels if power companies could produce it cheaply. Fuel cells and solar cells have provided power for space programs, but they cost too much for individuals to use. Much research is needed to develop these and other resources into practical sources of energy for the future.

Improving efficiency. To make our existing energy resources last longer, scientists and engineers are working to develop more efficient methods of recovering, transporting, and using energy. Petroleum and mining experts are investigating more economical ways of removing oil, natural gas, and coal from the earth. In addition, engineers are designing more efficient transportation systems to reduce the loss of energy as fuel is transported.

Engineers also can make our shrinking fuel reserves last longer by designing more efficient power plants and engines. Despite great improvements in the energy efficiency of automobiles and trucks, a gasoline engine still uses only about 20 percent of the total energy available in gasoline. The rest of the energy becomes wasted heat. Power-plant designers are developing plants that can turn more of the energy in fuel into electric energy, thereby saving fuel.

Conserving energy and using it wisely will also make the energy supply last longer. Such simple acts as raising thermostat settings in summer, lowering them in winter, and turning off unneeded lights help conserve energy. Improved building construction, better insulation, and use of solar cells could save up to half the energy used for heating and cooling. Travel by bus, train, or car pool reduces energy consumption. The recycling of paper and of aluminum, glass, and plastic containers greatly reduces the amount of energy used in manufacturing new products. Peter J. Catania



Los Alamos Scientific Laboratory

An experimental fusion device called Scyllac operates at the Los Alamos Scientific Laboratory. Scientists hope that nuclear fusion will someday provide a source of energy.

Related articles in *World Book* include:

Biomass
Bituminous sands
Coal
Electric generator
Electric power
Electricity
Energy
Environmental pollution (Global efforts)
Fuel
Fuel cell
Gas (fuel)
Gasoline
Heating (Sources of heat)
Industry (Energy supply)
Nuclear energy
Oil shale
Petroleum
Solar energy
Synthetic fuel
Turbine
Water power
Wind power

Outline

I. Sources of energy
- A. Fossil fuels
- B. Water power
- C. Nuclear energy
- D. Wood
- E. Solar energy
- F. Wind power
- G. Tidal energy
- H. Chemical energy
- I. Geothermal power
- J. Fuel cells
- K. Solid and liquid wastes
- L. Hydrogen
- M. Magnetohydrodynamic (MHD) generators

II. History

III. Problems
- A. Depletion of fuel reserves
- B. Environmental effects

IV. Challenges
- A. Developing new energy sources
- B. Improving efficiency
- C. Conserving energy

Questions

What are fossil fuels?
What was the first source of energy used by human beings, other than their own strength and direct sunlight?
What two resources might provide petroleum in the future?
Why did energy use in the United States decline during the early 1980's?
What is *acid rain?*
What is the difference between fission and fusion?
What substance ranked as the most important fuel throughout most of history?
What is the most abundant fossil fuel?
What steps can people take to conserve energy?
What is the *greenhouse effect?*

Additional resources

Level I

Graham, Ian. *Energy Forever?* 5 vols. Raintree Steck-Vaughn, 1999. Each volume in this series focuses on a different energy source.
Parker, Steve. *Fuels for the Future.* Raintree Steck-Vaughn, 1998.
Silverstein, Alvin, and others. *Energy.* 21st Century Bks., 1998.

Level II

Cassedy, Edward S. *Prospects for Sustainable Energy.* Cambridge, 2000.
Smil, Vaclav. *Energies: An Illustrated Guide to the Biosphere and Civilization.* MIT Pr., 1999.
Zumerchik, John, ed. *Macmillan Encyclopedia of Energy.* 3 vols. Macmillan, 2001.

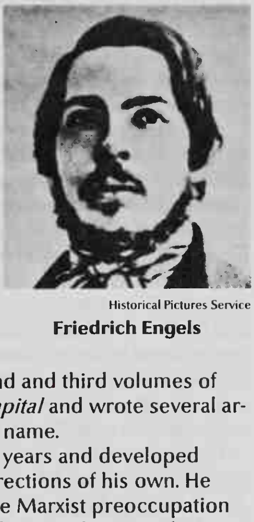
Enewetak, *EH nuh WEE tahk,* is an isolated atoll in the northwest corner of the Marshall Islands, in the Pacific Ocean. It consists of 40 low, sandy *islets* (small islands) that surround a lagoon. It has a land area of $2\frac{1}{4}$ square miles (6 square kilometers). The lagoon covers 388 square miles (1,005 square kilometers).

In 1944, during World War II, U.S. naval forces captured Enewetak from Japanese troops. In 1947, the U.S. government decided to use Enewetak for testing nuclear weapons. The government moved the inhabitants to Ujelang, another atoll. The tests lasted until the late 1950's and left the atoll contaminated by radiation. Later, the United States conducted a cleanup operation to reduce the radiation. The inhabitants were allowed to resettle on Enewetak in 1980. A marine laboratory built there by the United States has conducted valuable studies of sea and land plants and animals of the atoll.

From 1947 to 1986, Enewetak and the rest of the Marshalls were part of the Trust Territory of the Pacific Islands, which was administered by the United States. In 1986, the United States granted independence to the Marshalls (see **Marshall Islands**). Robert C. Kiste

Engels, *EHNG uhls,* **Friedrich,** *FREE drihkh* (1820-1895), was a German social scientist, journalist, and professional revolutionary. He is known chiefly for his long and close collaboration with Karl Marx, the founder of revolutionary Communism.

Engels made important contributions to Marxist theory, of which the most important was his introduction of Marx to the study of economics. Marx's knowledge of military and political affairs also came largely from Engels. See **Marx, Karl.**



Historical Pictures Service

Friedrich Engels

Engels and Marx wrote many books together. The most famous is the *Communist Manifesto* (1848), of which Engels wrote the first draft. He edited the second and third volumes of Marx's influential book *Das Kapital* and wrote several articles published under Marx's name.

Engels outlived Marx by 12 years and developed some of their joint ideas in directions of his own. He was largely responsible for the Marxist preoccupation with the scientific method and the application of Marxist views to all areas of knowledge. Some scholars believe that in his philosophic writings, Engels showed a misunderstanding of his friend's ideas.

Engels was born in Barmen, Prussia, the son of a textile manufacturer. Hunted by the police because of his revolutionary activities, he fled from Prussia in 1844. He returned during the revolution of 1848 but fled again after the revolution collapsed. He then settled in England, where he managed one of his father's factories. He earned enough to support Marx and his family.

Engels was well read in many languages and on a wide variety of topics. He was a keen observer with a creative mind, and some scholars believe that many of his works were far ahead of his time. He wrote on such diverse topics as religious history, anthropology, foreign affairs, the life of the working class, and especially military technology, his favorite subject. *The Condition of the Working Class in England* (1844) is a pioneering description of life in English working-class slums. *Herr Eugen Dühring's Revolution in Science* (1878), which is a popular presentation of Marxist theory, became the textbook for generations of Socialists and Communists. Other works by Engels dealt with German radical philosophy and the German revolution of 1848 and 1849.

Alfred G. Meyer

Engine is a machine that converts energy into mechanical work. An engine may get its energy from any of a number of sources, including fuels, steam, and air or water under pressure.

Reciprocating gasoline engines use the chemical energy of burning gasoline to push one or more pistons. The motion of the pistons can then be converted into *rotary* (circular) motion, which can be used to turn the wheels of an automobile or to do some other kind of work. Gasoline engines and steam engines are called *heat engines* because they convert heat energy into mechanical work. Reciprocating gasoline engines are called *internal-combustion engines* if the gases produced by the *combustion* (burning) of the fuel push directly against the pistons.

The steam engine is an *external-combustion engine.* External-combustion engines also get their energy from hot gases produced by burning. These gases transfer heat energy to another fluid. The energy in this fluid, in turn, is converted into mechanical work. In a piston steam engine, for example, heat of combustion is transferred to water inside a boiler. The heat converts the water to steam, which pushes the engine's pistons.

In *hydraulic engines,* water pressure is used to produce mechanical work. The pressure may be created by a pump or by water flowing downward from a level above the engine. William H. Haverdink

Related articles in *World Book* include:

Airplane (Power for flight)	Gasoline engine	Locomotive
Automobile (The power system)	Governor	Rocket
Diesel engine	Heat (Changing heat into motion)	Rotary engine
Electric motor	Hydraulic engine	Ship (The chief parts of a ship)
Flywheel	Internal-combustion engine	Steam engine
Free-piston engine	Jet propulsion	Stirling engine
		Turbine

Engine analyzer is an instrument used to determine the performance of parts of gasoline and diesel engines. An engine analyzer attaches directly to the engine. Mechanics and car owners use such analyzers to help adjust engine parts.

Engine analyzers range in design from simple models, which monitor a few engine functions, to complex, computerized models. Engine analyzers consist of a number of devices, such as an *oscilloscope* and a *tachometer.* An oscilloscope evaluates the ignition system. A tachometer assists in adjusting idle speed.

Most automobiles produced today include an internal computer that controls and monitors the engine. A computerized engine analyzer can be connected to this computer and can obtain detailed information about the engine's condition from it. Most computerized engine analyzers include such parts as a keyboard, display screen, and printer. William H. Haverdink

See also **Diesel engine; Gasoline engine.**

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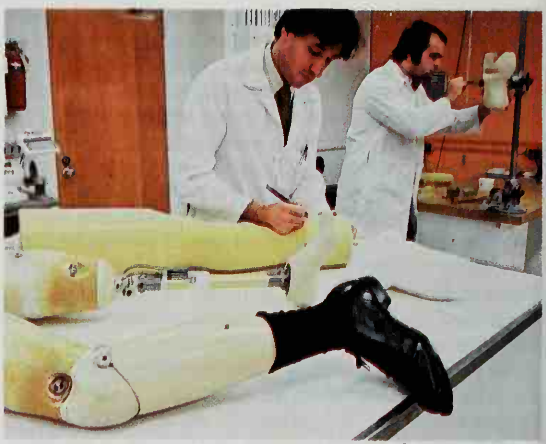
Civil engineers inspecting a building site



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Biomedical engineers designing artificial limbs

The field of engineering includes a broad range of activities—from planning and supervising large construction projects to designing and producing aids for people with disabilities.

Engineering

Engineering is the profession that puts scientific knowledge to practical use. The word *engineering* comes from the Latin word *ingeniare,* which means *to design* or *to create.* Engineers use principles of science to design structures, machines, and products of all kinds. They look for better ways to use existing resources and often develop new materials. Engineers have had a direct role in the creation of most of modern *technology*—the tools, materials, techniques, and power sources that make our lives easier (see **Technology**).

The field of engineering includes a wide variety of activities. For example, engineering projects range from the construction of huge dams to the design of tiny electronic circuits. Engineers help produce industrial robots or artificial limbs for people with disabilities. They develop complex scientific equipment to explore the reaches of outer space and the depths of the oceans. Engineers also plan our electric power and water supply systems, and do research to improve automobiles, personal computers, and other consumer products. They work to reduce environmental pollution, increase the world's food supply, and make transportation faster and safer.

In ancient times, there was no formal engineering education. The earliest engineers built structures and developed tools by trial and error. Today, special college training prepares engineers to work in a certain branch or field of engineering. Standards of quality and performance guide engineers on the job.

The branches of engineering

Most of the specialized fields of engineering developed about 1750 or later. Before 1750, engineering dealt mostly with energy needs and with the construction of buildings, roads, bridges, canals, or weapons. As people gained more knowledge of science and technology during the 1700's and 1800's, engineers began to specialize in certain kinds of work.

Today, new fields of engineering are continually emerging as a result of scientific and technological breakthroughs. At the same time, the boundaries between the various fields are becoming less and less clear-cut. Numerous areas of engineering overlap, and engineers from different specialties often work closely together on projects.

Aerospace engineering involves the design, production, and maintenance of commercial and military aircraft. Engineers in the aerospace field also play an essential role in the development and assembly of guided missiles and all types of spacecraft. Aerospace engineers help build wind tunnels and other testing equipment with which they carry out experiments on proposed craft to determine their performance, stability, and control under flight conditions. Aerospace research ranges from efforts to design quieter and more fuel-efficient commercial aircraft to the search for materials that can withstand the high radiation levels and extreme temperatures of space flight.

To design strong, safe vehicles, aerospace engineers must know and put into practical use the principles of *aerodynamics,* the study of the forces acting on an object due to air moving past it. They must also have a thorough understanding of the strength, elasticity, and other properties of the materials they use and be able to predict how they will behave during flight. Aerospace engineers work closely with electrical engineers in developing guidance, navigation, and control instruments and with mechanical engineers in designing suitable engines. They also assist civil engineers in planning airport facilities.

Biomedical engineering applies engineering techniques to health-related problems. Biomedical engineers develop aids for people with physical disabilities. They design artificial limbs, organs, and other devices that assist or replace diseased or damaged parts of the body. They produce such equipment as instruments that measure blood pressure and pulse rate and *surgical*

lasers—concentrated beams of light that can be used to perform delicate operations. Biomedical engineers also develop machines and techniques for viewing internal organs and methods for delivering medicines to specific internal sites. Some specialize in programming computer systems to monitor a patient's health or to process complex medical data, such as a person's genetic code.

In choosing materials for artificial aids and organs, biomedical engineers must understand the physical and chemical properties of the materials and how they interact with each other and with the human body. In their work, biomedical engineers often use principles of biology, chemistry, and medicine and of electrical, materials, and mechanical engineering. See **Biomedical engineering.**

Chemical engineering deals with the large-scale processing of chemicals and chemical products for industrial and consumer uses. Chemical engineers are concerned with the chemical processes that change raw materials into useful products. They plan, design, and help construct chemical plants and equipment and work to develop efficient and economical production methods. Many chemical engineers work for manufacturers of cosmetics, explosives, fertilizers and other agricultural chemicals, food products, fuels, *pharmaceuticals* (medical drugs), or plastics.

Chemical engineers must know how to handle and transport large quantities of chemicals. They have to understand such problems as heat transfer from one substance to another, absorption of liquids and gases, and evaporation. Chemical engineers control such processes as distillation, crystallization, filtration, mixing, drying, and crushing.

The work of chemical engineers relies heavily on principles of chemistry, physics, and mathematics, and frequently those of biology as well. Chemical engineers consult with electrical, mechanical, and industrial engineers in the design of plants and equipment. Some chemical engineers work closely with environmental engineers in seeking safe disposal methods for hazardous by-products of chemical processing.

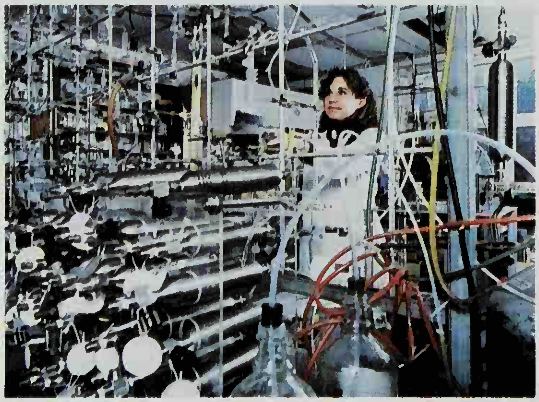
Civil engineering, the oldest of the main branches of engineering, involves the planning and supervision of such large construction projects as bridges, canals, dams, tunnels, and water supply systems. Civil engineers also cooperate with architects to design and erect all types of buildings. Other civil-engineering projects include airports, highways, levees, irrigation and sewerage systems, pipelines, and railroads.

Civil engineers work to build strong, safe structures that meet building codes and other regulations and are well suited to their surroundings. The engineers are responsible for surveying and preparing building sites and for selecting appropriate materials. Civil engineers must also understand the use of bulldozers, cranes, power shovels, and other construction equipment.

Some civil engineers specialize in the study of the physical characteristics of soils and rocks and the design of foundations. Others concentrate on the management of water resources, including the construction of flood control and irrigation systems, hydroelectric power plants, and water supply and sewerage systems. Still others are concerned with designing transportation systems and methods of traffic control. Many civil engi-

© David R. Frazier

An aerospace engineer at an assembly plant checks a guided missile while a worker looks on. Aerospace engineers also play a key role in the production of airplanes and spacecraft.



© Hans Namuth, Photo Researchers

A chemical engineer uses laboratory tests to determine which processing methods are the most economical and efficient. The best methods will be adapted to large-scale chemical plants.

© Sepp Seitz, Woodfin Camp, Inc.

Electrical engineers develop a wide variety of electrical and electronic devices. These electrical engineers are reviewing a greatly enlarged design for a single tiny electronic circuit.

neers are involved in city planning and urban renewal programs (see **City planning; Urban renewal**).

Computer engineering deals with the design of products for electronic computation and communication. Computer engineers focus on the creation, processing, and distribution of electronic information.

Computer engineers work in virtually all industries. They build computers for home and industrial use. They also make tiny computers that are used in products that range from cellular telephones to coffeemakers. Some computer engineers write and *upgrade* (revise and improve) *software*—coded instructions that tell computers how to accomplish specific tasks. Others develop networks that connect individual computers to one another worldwide and within local regions. Still another task of computer engineers is applying computer tools to specific tasks that range from patient management in hospitals to the development of mathematical models that can predict weather patterns.

Computer engineers rely on mathematics, physics, and electrical engineering. They may be called to work with experts in virtually any other field.

Electrical engineering involves the development, production, and testing of electrical and electronic devices and equipment. Electrical engineers design equipment to produce and distribute electric power. This equipment includes generators run by water power, coal, oil, and nuclear fuels; transmission lines; and transformers. Electrical engineers also design and develop electric motors and other electrical machinery as well as ignition systems used in automobiles, aircraft, and other engines. They work to improve such devices as air conditioners, food processors, and vacuum cleaners.

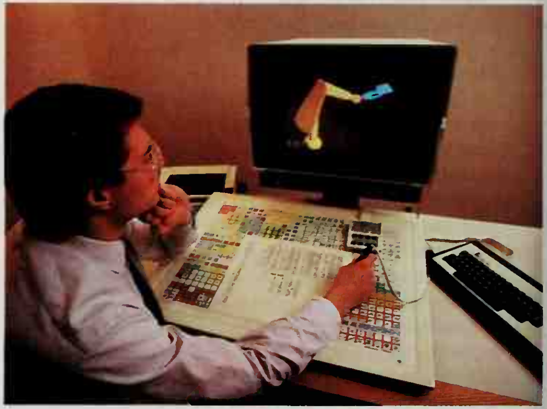
Electrical engineers play an essential role in the production of communications satellites, computers, industrial robots, medical and scientific instruments, missile control systems, and radar, radio, and television sets. Some engineers in the electronics field develop master plans for the parts and connections of miniature *integrated circuits*, which control the electric signals in most electronic devices. Telecommunication, which involves the transmission of messages over long distances, is another major specialty of electrical engineering.

Environmental engineering concerns efforts to prevent and control air, water, soil, and noise pollution. Environmental engineers develop equipment to measure pollution levels and conduct experiments to determine the effects of various pollutants. They design air pollution control devices and operate water purification systems and water treatment plants. Environmental engineers also develop techniques to protect the land from erosion and from pollution by chemical fertilizers and pesticides. They use computers to create mathematical models that help predict the results of the adoption of such techniques.

Environmental engineers are specialists in the disposal of hazardous wastes from factories, mining operations, nuclear power plants, and other sources (see **Hazardous wastes**). They work to clean up unsafe dump sites created in the past and do research on new storage and recycling techniques. Environmental engineers are also involved in the development of cleaner and more reliable forms of energy and in developing ways to make the best present and future use of natural re-

Gary Milburn, Tom Stack & Assoc.

Environmental engineers are concerned with preventing and controlling pollution. These engineers are checking for leakage and contamination at a dump site for hazardous wastes.



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An industrial engineer uses a computer to design an automated robot for an assembly line. Industrial engineers work continually to improve the production of goods and services.

© Odyssey Productions

Materials engineers may work with metals, ceramics, or plastics. These metallurgical engineers are supervising the pulverizing of silver ore, one step in obtaining the pure metal.

sources. Environmental engineers work with agricultural and mining engineers to develop production techniques that do the least possible damage to the land. They assist civil engineers in the design of water supply, waste disposal, and ventilation systems, and they help chemical and nuclear engineers in waste disposal.

Industrial engineering applies engineering analysis and techniques to the production of goods and services. Industrial engineers determine the most economical and effective ways for an organization to use people, machines, and materials. An industrial engineer may select the location for a plant or office, determine employee requirements, select equipment and machinery, lay out work areas, and plan steps in operations. Industrial engineers also develop training and job evaluation programs and work-performance standards, and help determine wages and employee benefits. They work to solve such problems as high costs, low productivity, and poor product quality.

Mathematical models developed on computers enable industrial engineers to simulate the flow of work through an organization and to evaluate the effects of proposed changes. Industrial engineers also use data-processing systems to aid in financial planning, inventory control, and scheduling. Their work often requires a knowledge of mathematics, economics, psychology, and personnel management. Industrial engineers work in a wide variety of businesses and industries, including banks, construction and transportation firms, government agencies, hospitals, and public utilities.

Materials engineering deals with the structure, properties, production, and uses of various materials. Materials engineers work with both metallic and nonmetallic substances. They improve existing materials and develop new uses and production methods for them. They also develop new materials to meet specific needs. The major subdivisions of engineered materials are metals, ceramics, and *polymers* (plastics). Another important category is *composites,* which combine at least two different materials to achieve specific properties. See **Metallurgy; Ceramics; Plastics; Composite materials.**

Materials engineers are involved in nearly all industries. They help develop and determine the best materials to use for various products. Materials engineers have developed lightweight, high-strength materials for use in aircraft parts; materials to withstand high temperatures for the nuclear power industry; materials for use inside the human body; and materials designed to break down into simple compounds with minimal impact on the environment.

Materials engineers frequently work with chemical, industrial, and mechanical engineers. They may also work with biomedical, electrical, or environmental engineers. They rely on principles of physics, chemistry, mathematics, and often those of biology.

Mechanical engineering deals with the physical behavior of solids and fluids and with systems of solids and fluids. Mechanical engineers are involved in the development of mechanical, biomechanical, and electromechanical processes; the production, transmission, and use of mechanical power; the flow of fluids and heat in systems; and the control of mechanical operations. Applications of mechanical engineering include machinery design and development and the creation of products with moving parts, which range from children's toys to automobiles to power plants.

Mechanical engineers work in many industries, including public utilities, energy production, transportation, and manufacturing. They help design products used to study the human body or to replace parts of the body. For example, mechanical engineers have developed mathematical models of human motion that have been applied to both mobile robots and biomedical devices. They have also played a key role in the development of miniature electromechanical devices, such as portable tape and compact disc players.

Mechanical engineers rely on the principles of physics and mathematics. Those involved in certain tasks might also rely on knowledge of biology, chemistry, electrical engineering, and materials engineering.

Nuclear engineering is concerned with the production and applications of nuclear energy and the uses of radiation and radioactive materials. Most nuclear engineers design, construct, and operate nuclear power plants that generate electric power. They handle every stage in the production of nuclear energy, from the processing of nuclear fuels to the disposal of radioactive wastes from nuclear reactors. They also work to improve and enforce safety standards and to develop new types of nuclear energy systems.

Nuclear engineers also design and build nuclear engines for ships, submarines, and space vehicles. They develop industrial, medical, and scientific uses for radiation and radioactive materials. Some nuclear engineers specialize in designing and constructing *particle accelerators,* devices used in scientific studies of the atom and in creating new elements. Others specialize in the development of nuclear weapons. Nuclear engineers also play a role in the development of radiation sources, detectors, and shielding equipment. The work of nuclear engineers frequently overlaps with that of electrical, environmental, mechanical, and materials engineers.

Other specialized fields focus on even more specific areas of engineering than do the major branches. This section describes a few important specialties.

Acoustical engineering deals with sound. The work of acoustical engineers includes designing buildings and rooms to make them quiet; improving conditions for listening to speech and music in auditoriums and halls; and developing techniques and sound-absorbing materials to reduce noise pollution.

Agricultural engineering involves the design of farm buildings and agricultural equipment, and erosion control, irrigation, and land conservation projects. Agricultural engineers are also concerned with the processing, transporting, and storing of agricultural products.

Mining engineering involves locating and appraising deposits of minerals and ores. Mining engineers decide how they may mine these materials as cheaply, efficiently, and safely as possible.

Ocean engineering involves the design and installation of all types of equipment used in the ocean. The products of ocean engineers include oil rigs and other offshore installations, marine research equipment, and breakwater systems used to prevent beach erosion.

Petroleum engineering deals with producing, storing, and transporting petroleum and natural gas. Petroleum engineers locate oil and gas deposits and try to

Mark Antman, Image Works

A mechanical engineer makes adjustments to a wind turbine. Mechanical engineers are involved in every phase in the development of a machine, from its design to its final installation.

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A nuclear engineer, *foreground,* monitors the central control room of a nuclear power plant. Nuclear engineers also help process nuclear fuels and dispose of radioactive wastes.

develop more efficient drilling and recovery methods.

Textile engineering is concerned with the machinery and processes used to produce both natural and synthetic fibers and fabrics. Engineers in this field also work to develop new and improved textiles.

Transportation engineering involves efforts to make transportation safer, more economical, and more efficient. Engineers in this field design all types of transportation systems and develop related facilities for reducing traffic problems.

History

The history of engineering is the record of human ingenuity through the ages. Even in prehistoric times, people adapted basic engineering techniques from things that were available in nature. For example, sturdy sticks became levers to lift large rocks, and logs were used as rollers to move heavy loads. The development of agriculture and the growth of civilization brought about a new wave of engineering efforts. People invented farming tools, designed elaborate irrigation networks, and built the first cities. The construction of the gigantic Egyptian pyramids at Giza during the 2500's B.C. was one of the greatest engineering feats of ancient times. In ancient Rome, engineers built large aqueducts and bridges and vast systems of roads. During the 200's B.C., the Chinese began building walls to link older walls to protect China's northern border. These links marked the start of the construction of the Great Wall of China.

Early engineers used such simple machines as the inclined plane, wedge, and wheel and axle. During the Middle Ages, a period in European history that lasted from the A.D. 400's to the 1500's, inventors developed machines to harness water, wind, and animal power. The growing interest in new types of machines and new sources of power to drive them helped bring about the Industrial Revolution, a period of rapid industrial development in the 1700's and 1800's. The role of engineers expanded rapidly during the Industrial Revolution. The practical steam engine developed by the Scottish engineer James Watt in the 1760's revolutionized transportation and industry by providing a cheap, efficient source of power. New ironmaking techniques provided engineers with the material to improve machines and tools and to build bridges and ships. Many roads, railroads, and canals were constructed to link the growing industrial cities.

Distinct branches of engineering began to develop during the Industrial Revolution. The term *civil engineer* was first used about 1750 by John Smeaton, a British engineer. Mechanical engineers emerged as specialists in industrial machinery, and mining and metallurgical engineers were needed to supply metals and fuels. By the late 1800's, the development of electric power and advances in chemical processing had created the fields of electrical and chemical engineering. Professional schools began to be founded as the demand for engineers steadily increased.

During the 1900's, the number of engineers and of engineering specialties expanded dramatically. Airplanes, computers, lasers, nuclear energy, plastics, space travel, and television were among the scientific and technological breakthroughs that engineers helped achieve.

Science and technology have progressed and changed so rapidly that the engineers of the 2000's must study throughout their careers to ensure that their knowledge and expertise do not become obsolete. They face the challenging task of keeping pace with the latest advances while working to shape the technology of the future.

Engineering careers

The field of engineering offers a broad range of job opportunities. Engineers may work in factories, offices, and government laboratories or at construction sites. Some engineers are involved in the research and development of new products. Others are responsible for turning plans and specifications for new structures, machines, or systems into reality. Still others use their background and training to sell and service technical equipment. Many engineers work on projects in teams that include scientists, technicians, and other engineers. But

some engineers act as independent consultants who sell their services to people who need engineering assistance. Engineers may also hold teaching positions or move up into management positions in business.

Certain abilities and traits help qualify a person for an engineering career. Engineers must have technical aptitude and skill in mathematics and the sciences. They should be curious about the "how" and "why" of natural things and creative in finding new ways of doing things. Engineers need to be able to analyze problems systematically and logically and to communicate well—both orally and in writing. They should be willing to work within strict budgets and meet tight deadlines. In addition, skill in working as part of a team and in directing and supervising other workers is an important part of many engineering jobs.

Education and training. For students considering a career in engineering, the most important subjects to take in high school are mathematics and science. Typically, the mathematics courses should cover algebra, geometry, trigonometry, and introductory calculus. Chemistry and physics are important sciences for students to take. Helpful electives include biology; foreign languages; economics, history, and other social studies courses; and composition and public speaking.

To enter the engineering profession, most students complete a four-year bachelor's degree program at a college or university. In addition to a course of study in their chosen engineering fields, engineering students must take several advanced mathematics and science courses. Most undergraduate degree programs also include courses in such subjects as economics, history, languages, management, and writing to equip students with the skills that will be needed in their later work as engineers. Many programs require the completion of an independent study or design project, including a formal report, before graduation.

Undergraduate engineering students often take part in *internships* or *cooperative education* programs in which they alternate between going to school and working for companies as special engineering trainees. These programs give students the benefit of practical experience while studying for their degrees.

Graduate study gives the engineering student additional preparation for a professional career. Many engineering students study for an additional year or two after receiving a bachelor's degree. They undertake a program of advanced course work in a specialized field and earn a master's degree. The completion of an original research project called a *thesis* is part of most master's programs. Engineering students who want to teach at a college or university or do advanced research may then study three to five more years to earn a doctor's degree.

Some universities, junior and community colleges, and technical institutes offer two-year and four-year degree programs in certain specialized areas of engineering technology, such as computer maintenance and electronics. Engineering technology programs prepare students for basic design and production work in engineering rather than for jobs that require extensive knowledge of science or mathematical theory. *Engineering technicians,* graduates of the two-year programs, and *engineering technologists,* graduates of the four-year programs, form an important part of professional engineering teams.

Engineers continue their education after they complete their formal studies and obtain a job. Engineers, as well as engineering technicians and technologists, must continually update their knowledge by taking courses, attending workshops offered by professional societies, and reading technical journals.

Registration and licensing. Laws affecting the registration and licensing of engineers vary from country to country. In many countries, engineers must be registered if they offer their services to the public or if they are involved in construction. In the United States, each state has a board of engineering examiners that administers the licensing laws.

Professional organizations and standards. Many specialized fields of engineering have their own professional societies. The societies publish technical articles and help members keep up to date. They also grant awards to outstanding engineers, work to promote public understanding of engineering, and encourage young people to become engineers. Many engineering societies prepare standards for procedures and sponsor research of general interest.

Engineering organizations in the United States include the Accreditation Board for Engineering and Technology (ABET) and the American Association of Engineering Societies (AAES). Both are composed of several societies. The ABET reviews and accredits courses of study in engineering and engineering technology. It also provides guidance material for high school and college students. The AAES helps its member societies coor-

Some engineering societies

American Institute of Aeronautics and Astronautics Suite 500, 1801 Alexander Bell Drive, Reston, VA 20191-4344; http://www.aiaa.org

American Institute of Chemical Engineers 3 Park Avenue, New York, NY 10016-5991; http://www.aiche.org

American Institute of Mining, Metallurgical, and Petroleum Engineers 3 Park Avenue, New York, NY 10016-5998; http://www.aimeny.org

American Nuclear Society 555 N. Kensington Avenue, LaGrange Park, IL 60526; http://www.ans.org

American Society of Civil Engineers 1801 Alexander Bell Drive, Reston, VA 20191-4400; http://www.asce.org

American Society of Mechanical Engineers 3 Park Avenue, New York, NY 10016-5990; http://www.asme.org

Engineering Institute of Canada 1980 Ogilvie Road, Gloucester, ON K1J 9L9; http://www.eic-ici.ca

Institute of Electrical and Electronics Engineers 3 Park Avenue, New York, NY 10016-5997; http://www.ieee.org

Institute of Industrial Engineers Suite 200, 3577 Parkway Lane, Norcross, GA 30092; http://www.iienet.org

Institution of Civil Engineers 1 Great George Street, Westminster, London SW1P 3AA, United Kingdom; http://www.ice.org.uk

Institution of Electrical Engineers Savoy Place, London WC2R 0BL, United Kingdom; http://www.iee.org.uk

Institution of Engineers, Australia 11 National Circuit, Barton, ACT 2600, Australia; http://www.ieaust.org.au

Institution of Engineers (India) 8 Gokhale Road, Kolkata 700020, India; http://ieindia.org

Institution of Mechanical Engineers 1 Birdcage Walk, London SW1H 9JJ, United Kingdom; http://www.imeche.org.uk

Society of Women Engineers Suite 400, 230 E. Ohio Street, Chicago, IL 60611-3265; http://www.swe.org

dinate activities and exchange information on matters of general interest to the engineering profession.

Many professional engineers in the United States observe a code of ethics called *Canons of Ethics of Engineers,* which is recognized by the ABET. The code tells how engineers should conduct themselves in dealing with the public, with clients and employers, and with other engineers. Ilene J. Busch-Vishniac

Related articles in *World Book* include:

American engineers

Armstrong, Edwin H.
Armstrong, Neil A.
Corliss, George H.
Edgerton, Harold E.
Ellsworth, Lincoln
Ericsson, John
Gilbreth, Frank and Lillian
Goethals, George W.
Greenway, John C.
Hammond, John H., Jr.
Kettering, Charles F.
Latrobe, Benjamin H.
Mills, Robert
Piccard (Jean)
Pupin, Michael I.
Roosevelt, Nicholas J.
Steinmetz, Charles P.
Stevens, John
Stevens, Robert L.
Taylor, Frederick W.
Tesla, Nikola
Von Braun, Wernher
White, Alfred Holmes

British engineers

McAdam, John L.
Nasmyth, James
Stephenson, George
Stephenson, Robert
Stevenson, Robert
Telford, Thomas
Trevithick, Richard
Watson-Watt, Sir Robert A.
Watt, James

French engineers

Coulomb, Charles A. de
Eiffel, Gustave
L'Enfant, Pierre C.
Lenoir, Jean J. E.

German engineers

Benz, Karl
Daimler, Gottlieb
Diesel, Rudolf
Maybach, Wilhelm

Other engineers

Fleming, Sir Sandford
Gabor, Dennis
Marconi, Guglielmo

Aerospace engineering

Aerodynamics
Airplane
Airship
Glider
Guided missile
Helicopter
Jet propulsion
Rocket
Satellite, Artificial
Space exploration
Streamlining
Wind tunnel

Biomedical engineering

Artificial limb
Biomedical engineering
Cryobiology
Electrocardiograph
Electroencephalograph
Hearing aid
Laser

Chemical engineering

Chemistry
Forest products
Rubber
Synthetics

Civil engineering

Aqueduct
Architecture
Bridge
Building construction
Caisson
Canal
Cantilever
City planning
Cofferdam
Dam
Drainage
Dredging
Hydraulics
Irrigation
Reservoir
Road
Sewage
Surveying
Tunnel
Viaduct

Computer engineering

Computer
Computer chip

Electrical engineering

Electric generator
Electric light
Electric motor
Electricity
Electronics
Lighting
Radar
Radio
Servomechanism
Telegraph
Telephone
Television
Transformer

Environmental engineering

Conservation
Environmental pollution
Hazardous wastes
Waste disposal

Industrial engineering

Assembly line
Automation
Ergonomics
Manufacturing
Mass production
Nanotechnology

Materials engineering

Ceramics
Composite materials
Iron and steel
Materials
Metallurgy
Plastics
Powder metallurgy

Mechanical engineering

Air conditioning
Automobile (Building an automobile)
Bearing
Brake
Engine
Heating
Machine
Machine tool
Pump
Refrigeration
Tool
Turbine

Nuclear engineering

Nuclear energy
Nuclear physics
Particle accelerator
Radiation

Other related articles

Bionics
Coal
Communication
Computer graphics (In engineering)
Cybernetics
Egypt, Ancient (Architecture; pictures)
Gas (fuel)
Great Wall of China
Greece, Ancient (The arts; pictures)
Indian, American
Industrial Revolution
Invention
Mathematics
Medicine
Mineral
Mining
Ore
Petroleum
Pyramids
Roman walls
Rome, Ancient (Transportation and communication; Architecture and engineering)
Science
Seven Wonders of the Ancient World
Technology
Transportation

Outline

I. The branches of engineering
A. Aerospace engineering
B. Biomedical engineering
C. Chemical engineering
D. Civil engineering
E. Computer engineering
F. Electrical engineering
G. Environmental engineering
H. Industrial engineering
I. Materials engineering
J. Mechanical engineering
K. Nuclear engineering
L. Other specialized fields

II. History

III. Engineering careers
A. Education and training
B. Registration and licensing
C. Professional organizations and standards

Questions

What were some of the achievements of ancient engineers?
When did distinct engineering fields begin to emerge?
Why must engineers study throughout their careers?
What is the *Canons of Ethics of Engineers*?
What types of machines were used by early engineers?
When did inventors begin to develop machines to harness water, wind, and animal power?
What does a biomedical engineer do? An acoustical engineer?
What are some of the abilities and traits that help qualify a person for an engineering career?
What are some of the functions of professional engineering societies?

What are *internship* and *cooperative education* programs?
How does the work of environmental engineers overlap with that of agricultural and mining engineers?

Additional resources

Adams, James L. *Flying Buttresses, Entropy, and O-Rings: The World of an Engineer.* Harvard Univ. Pr., 1991.
Bortz, Fred. *Catastrophe! Great Engineering Failure—and Success.* Scientific Am. Bks., 1995. Younger readers.
Garrison, Ervan G. *A History of Engineering and Technology: Artful Methods.* CRC Pr., 1991.
Petroski, Henry. *Invention by Design: How Engineers Get from Thought to Thing.* Harvard Univ. Pr., 1996.
Rae, John, and Volti, Rudi. *The Engineer in History.* Peter Lang, 1993.
The Builders: Marvels of Engineering. National Geographic Soc., 1992.

Engineers, Corps of, is the branch of the United States Army that is responsible for military engineering as well as for many kinds of civil-engineering projects. The leader of the Corps of Engineers is a lieutenant general.

In peacetime, the corps plans and directs construction of navigation and flood control works for the federal government. These works include harbors, dams, and levees. The corps also is responsible for managing and restoring U.S. wetlands. In the early days, activities of the corps were broader. The corps built such public structures as the Washington Monument.

In wartime, fighting troops depend upon the Corps of Engineers for the building of military bridges, roads, airfields, military camps, and other installations. Army engineers draw, reproduce, and distribute maps throughout the Army. Units known as *combat engineers* work closely with front line troops. For example, they handle the assault boats, rafts, and bridging during river-crossing operations. They also place and clear mines and booby traps and demolish roads and bridges. Combat engineers often operate under enemy fire. They are prepared to fight as infantry troops if needed.

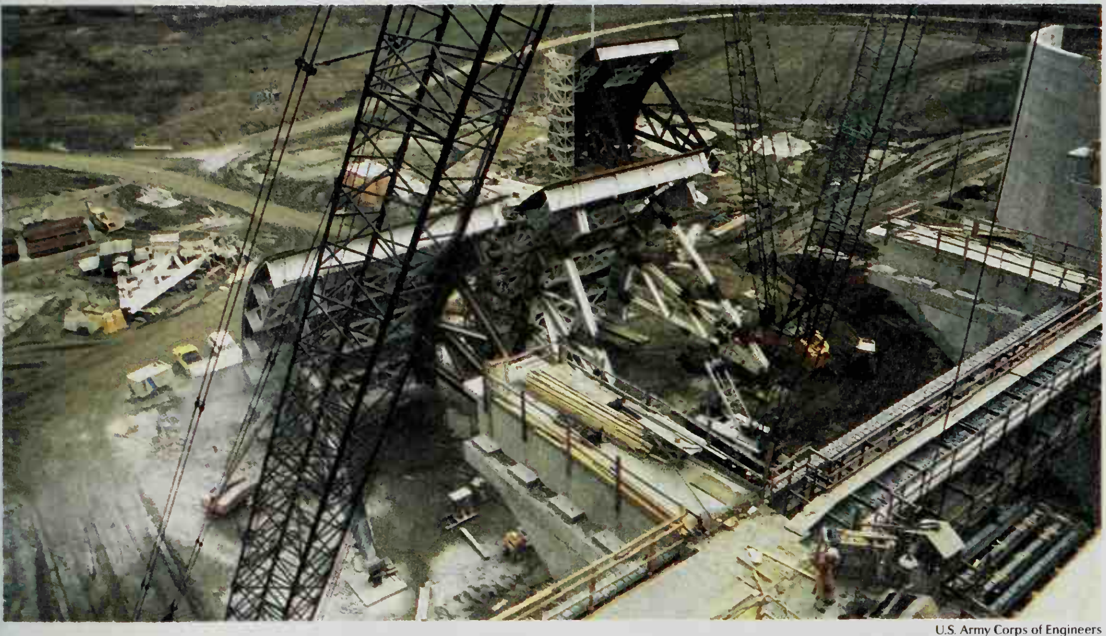
The corps as it is known today dates from 1802, when Congress authorized the president to organize the Corps of Engineers at West Point to "constitute a Military Academy." Members of the corps helped build such famous civil-engineering works as the Chesapeake and Ohio Canal and the Panama Canal. The Corps of Engineers supervised the $2 billion Manhattan Project that developed the first atomic bomb in 1945.

The Corps of Engineers has been criticized by environmental groups, which charge that the corps plans many projects with little regard for the environment. Since the 1960's, the groups have filed a number of lawsuits to delay or stop projects they consider harmful. As a result, the corps has modified many projects to minimize possible environmental damage. The corps must also prepare environmental impact statements before undertaking new projects that might have a significant impact on the environment. Joel Slackman

Engineers, International Union of Operating, is an international union affiliated with the American Federation of Labor and Congress of Industrial Organizations (AFL-CIO) and the Canadian Federation of Labour (CFL). Members include *hoisting engineers* and *portable engineers,* both of whom operate heavy machinery in the construction industry.

The union was founded in the United States in 1896. Its headquarters are in Washington, D.C. For membership, see **Labor movement** (table: Important U.S. labor unions).

Critically reviewed by the International Union of Operating Engineers



U.S. Army Corps of Engineers

The Corps of Engineers plans and supervises many civil-engineering projects. The project shown here is intended to limit the flow of the Mississippi River into the Atchafalaya River in Louisiana. The corps also handles military engineering for the United States Army.

© ZEFA

London's Piccadilly Circus is an intersection of six busy streets. This downtown area in England's capital is filled with theaters, restaurants, nightclubs, and shops.

England

England is the largest of the four political divisions that make up the United Kingdom of Great Britain and Northern Ireland. Northern Ireland, Scotland, and Wales are the other three political divisions of the United Kingdom, which is often called *Great Britain* or simply *Britain.* England is the industrial and trading center of the United Kingdom.

England lies in the southern and eastern part of the island of Great Britain. It covers about three-fifths of the island. England has much charming countryside, with green pastures and neat hedges. But most of the English people live in sprawling cities. London, the capital, is England's largest city.

England has a rich history. The Industrial Revolution, a period of rapid industrialization, began there in the 1700's. English sailors, traders, explorers, and colonists helped found the British Empire—the largest empire in history. England produced William Shakespeare, who is considered the greatest dramatist of all time, and Sir Isaac Newton, one of history's most important scientists.

The English people have a long history of freedom and democracy. Their democratic ideas and practices have influenced many countries, including the United States and Canada. Most English people take great pride in their history and have deep respect for England's customs and traditions.

The contributors of this article are Rodney Barker, Reader in Government at the London School of Economics; Peter R. Mounfield, Senior Lecturer in Geography at the University of Leicester, England; and Anthony Sutcliffe, Special Professor in the Department of History, University of Nottingham, England.

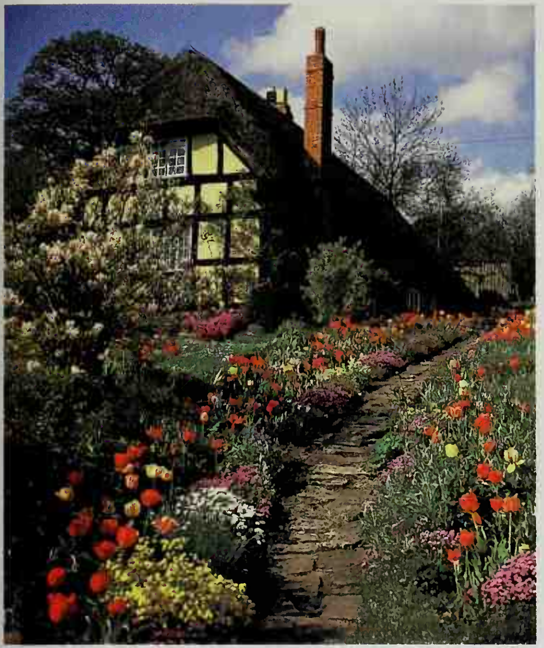
This article describes the people, geography, and economy of England. It also traces England's history up to 1707, when England and Wales were joined with Scotland to form a united kingdom of Great Britain. For a discussion of the United Kingdom as a whole and of its history since 1707, see the *World Book* article on **United Kingdom.**

Government

England is the leading political division of the United Kingdom. The government of the United Kingdom serves as England's government.

Facts in brief

Capital: London.
Official language: English.
Area: 50,352 mi² (130,410 km²). *Greatest distances*—north-south, about 360 mi (579 km); east-west, about 270 mi (435 km). *Coastline*—about 1,150 mi (1,851 km).
Elevation: *Highest*—Scafell Pike, 3,210 ft (978 m) above sea level. *Lowest*—Great Holme Fen, near the River Ouse in Cambridgeshire, 9 ft (2.7 m) below sea level.
Population: *Estimated 2002 population*—49,155,600; distribution, 95 percent urban, 5 percent rural; population density, 976 per mi² (377 per km²). *1991 census*—47,078,000.
Chief products: *Agriculture*—barley, cattle, chickens and eggs, fruits, milk, potatoes, sheep, sugar beets, wheat. *Fishing*—cod, haddock, mackerel. *Manufacturing*—aircraft engines, beverages, chemicals, clothing, electronic equipment, fabricated steel products, footwear, leather goods, paper, printed materials, processed foods, tobacco, wool and other textiles. *Mining*—coal, natural gas, petroleum.



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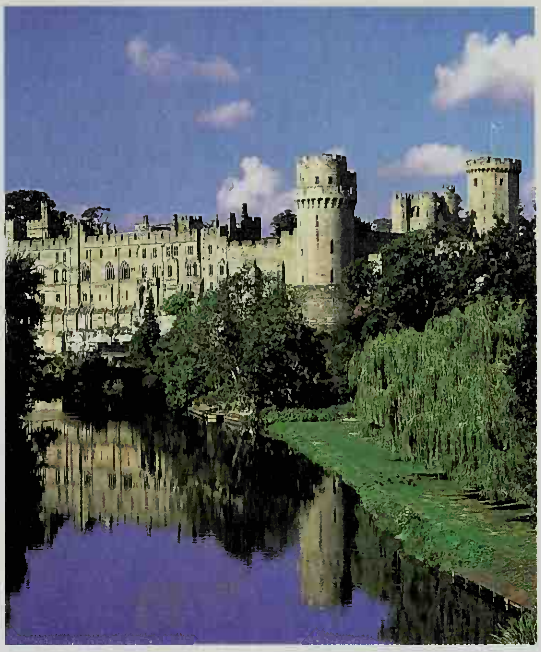
An English country cottage has a garden in full bloom. Gardening is a popular activity for many English people.

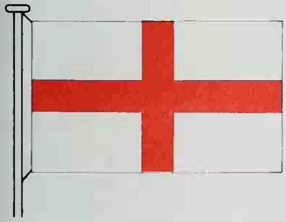


Robert Harding Picture Library

Warwick Castle, in central England, overlooks the River Avon. Much of its external structure is unchanged from the mid-1300's.

The United Kingdom is both a parliamentary democracy and a constitutional monarchy. Parliament, the chief lawmaking body of the United Kingdom, meets in London. Parliament consists of the monarch, the House of Commons, and the House of Lords. Queen Elizabeth II acts as head of state, but a group of senior members of parliament called the Cabinet actually governs the United Kingdom. The prime minister leads the government.

The House of Commons is the more powerful house. Its members are elected from each of the four political divisions that make up the United Kingdom. England elects 529 of the 659 members of the House of Commons. The House of Lords has limited power. Most of its members are honorary appointees. For more information on British government, see **United Kingdom** (Government).



England's flag is called *St. George's Cross.* The flag has never been officially adopted, but the English people have used it for over 700 years.

Royal arms of the British monarch are used in England. The sections of the shield with three gold lions on a red field represent England.

For purposes of local government, England is divided into a number of administrative units. These units include counties, metropolitan districts, and unitary authorities. The counties are further divided into shire districts. The Greater London area is divided into 32 boroughs and *the City.* The City is the oldest part of London and its financial district.

Each government unit has its own elected council. The government councils deal with such matters as education, housing, recreation, refuse collection, and road

WORLD BOOK map

England, Scotland, and Wales occupy the island of Great Britain. With Northern Ireland, they make up the United Kingdom.

construction and maintenance. Most of the money for these services comes from *council taxes,* which are paid by local residents, and from grants from the national government.

People

Population. Almost all of England's people live in urban areas. More than a third live in the seven metropolitan areas.

Greater London is the largest metropolitan area in England and one of the largest such areas in the world. It covers 614 square miles (1,590 square kilometers) and has about 6 $\frac{1}{2}$ million people. The six metropolitan counties, with the largest city of each in parentheses, are (1) Greater Manchester (Manchester), (2) Merseyside (Liverpool), (3) South Yorkshire (Sheffield), (4) Tyne and Wear (Newcastle upon Tyne), (5) West Midlands (Birmingham), and (6) West Yorkshire (Leeds).

Until the mid-1800's, most of the English people lived in the countryside. During the Industrial Revolution, huge numbers of people moved to cities and towns to work in factories, mines, and mills. By the beginning of the 1900's, about four-fifths of the people lived in cities.

During the 1800's and early 1900's, millions of people left England to settle elsewhere. From the 1930's to the 1960's, the number of people moving to England outnumbered those leaving. Since the 1970's, however, the number leaving has been slightly larger than the number of people entering England. Most of the English emigrants have gone to the United States or to Canada, Australia, New Zealand, or other countries that were once part of the British Empire.

Refugees from Europe flowed into England before and after World War II (1939-1945). Since the 1950's, a large number of immigrants have come from Pakistan and from countries in Asia and the West Indies that belong to the Commonwealth. The Commonwealth is an association of countries and other political units that were once part of the British Empire. Most of the immigrants have settled in cities and towns already facing housing shortages. During the early 1960's, the British government began restricting immigration. The wives and children of immigrants already living in England make up about half of the new immigrants who are accepted each year.

Ancestry. Celtic-speaking people lived in what is now England by the mid-600's B.C. Over the next 1,700 years, the land was invaded by the Romans, Angles, Saxons, Jutes, Danes, and Normans. The Normans, the last people to invade England, came in A.D. 1066. Each group of invaders added its own traditions and speech to English civilization and helped shape the character of the English people.

Language. English is the official language of the United Kingdom. It developed mainly from the Anglo-Saxon and Norman-French languages. For a discussion

England map index

Counties

Bedfordshire	514,200	G	5
Buckinghamshire	619,500	G	5
Cambridgeshire	640,700	F	6
Cheshire	937,300	E	4
Cornwall	469,300	I	1
Cumbria	486,900	C	3
Derbyshire	915,000	E	4
Devon	1,008,300	I	2
Dorset	645,200	I	4
Durham	589,800	C	4
East Sussex	670,600	H	6
Essex	1,495,600	G	6
Gloucestershire	520,600	G	4
Hampshire	1,511,900	H	5
Hertfordshire	951,500	G	6
Kent	1,485,600	H	7
Lancashire	1,365,100	D	4
Leicestershire	860,500	F	5
Lincolnshire	573,900	E	6
Norfolk	736,700	F	7
North Yorkshire	568,900	C	5
Northamptonshire	300,600	F	5
Northumberland	698,800	B	4
Nottinghamshire	980,600	E	5
Oxfordshire	553,800	G	4
Shropshire	401,600	F	3
Somerset	459,100	H	3
Staffordshire	1,020,300	E	4
Suffolk	629,900	F	7
Surrey	997,000	H	5
Warwickshire	477,000	F	4
West Sussex	692,800	H	5
Wiltshire	553,300	H	4
Worcestershire	667,800	F	4

Unitary authorities*

Bath and North East Somerset	157,600	H	4
Bournemouth	154,400	I	4
Brighton and Hove	215,900	H	6
Bristol	370,300	H	4
Darlington	96,700	C	4
Derby	214,000	F	4
East Riding of Yorkshire	306,200	D	5
Hartlepool	88,200	C	5
Isle of Wight	126,600	I	5
Kingston-upon-Hull	252,200	D	5
Leicester	270,600	F	5
Luton	167,300	G	5
Middlesbrough	141,100	C	5
Milton Keynes	172,300	G	5
North East Lincolnshire	156,400	D	6
North Lincolnshire	156,400	D	5
North Somerset	174,300	H	3
Poole	130,900	I	4
Portsmouth	174,700	H	4
Redcar and Cleveland	141,700	C	5
Rutland	32,400	F	5
South Gloucestershire	216,700	G	4
Southampton	194,400	H	4
Stockton-on-Tees	170,200	C	4
Stoke-on-Trent	244,800	E	4
Swindon	167,200	G	4
York	166,400	D	5

Cities and towns†

Aylesbury	139,400	G	5
Barnsley	217,300	E	5
Basildon	156,300	G	6
Bedford (North Bedfordshire district)	133,900	G	5
Birkenhead (Wirral district)	322,100	E	3
Birmingham	934,900	F	4
Blackburn	141,100	D	4
Blackpool	145,800	D	3
Bolton	253,300	E	4
Bournemouth	149,700	I	4
Bradford	449,100	D	4
Brighton and Hove‡	232,600	I	6
Bristol	370,300	H	4
Bury§	173,300	D	4
Calderdale§	191,700	D	5
Cambridge	98,700	G	6
Canterbury	127,400	H	7
Carlisle	101,300	C	3
Chelmsford	147,900	G	6
Chester	116,600	E	3
Chichester	101,700	I	5
Coventry	292,600	F	4
Derby	214,000	F	4
Doncaster	284,300	E	5
Dorchester (West Dorset district)	81,300	I	4
Dover	102,600	H	7
Dudley	300,400	F	4
Durham	85,000	C	4
Exeter	99,700	I	3
Gateshead	196,500	C	4
Glastonbury (Sedgemoor district)	93,000	H	3
Gloucester	91,100	G	4
Great Grimsby, see Grimsby			
Great Yarmouth	84,200	F	7
Grimsby	90,900	D	6
Hastings	80,200	H	7
Hertford (East Hertfordshire district)	116,900	G	6
Huddersfield (Kirklees district)	367,600	F	4
Hull	252,200	D	5
Ipswich	118,500	G	7
Kingston upon Hull, see Hull			
Kingston upon Thames	133,900	H	6
Knowsley§	166,300	E	4
Leeds	674,400	D	5
Leicester	282,900	F	5
Lewes	84,400	H	6
Lincoln	78,200	E	5
Liverpool	448,300	E	3
London (Greater London)	6,378,600	G	6
Luton	166,100	G	5
Maidstone	132,500	H	6
Manchester	397,400	E	4
Matlock (Amber Valley district)	108,800	E	4
Middlesbrough	144,800	C	5
Newcastle upon Tyne	263,000	B	4
Newport (Medina district)	69,700	I	5
North Tyneside§	193,200	B	5
Northallerton (Hambleton district)	76,000	C	4
Northampton	169,800	G	5
Norwich	122,300	F	7
Nottingham	279,400	E	5
Oldham	211,400	E	4
Oxford	115,000	G	5
Peterborough	144,600	F	6
Plymouth	253,400	I	2
Portsmouth	174,700	I	5
Preston	124,800	D	4
Reading	135,300	H	5
Rochdale	196,900	D	4
Rotherham§	247,100	E	5
St. Helens	188,300	E	3
Salford	217,900	E	4
Salisbury	102,500	H	4
Sandwell§	282,000	F	4
Sheffield	500,500	E	5
Shrewsbury	90,500	F	3
Solihull	195,100	F	4
South Shields (South Tyneside district)	157,600	B	5
Southampton	194,400	H	5
Southend-on-Sea	158,200	G	6
Southport (Sefton district)	282,000	D	3
Stafford	117,800	F	4
Stockport	276,800	E	4
Stockton-on-Tees§	175,800	C	5
Stoke-on-Trent	248,700	E	4
Stratford-upon-Avon	104,600	G	4
Sunderland	286,800	C	5
Swindon (Thamesdown district)	159,800	H	4
Tameside§	211,700	E	4
Taunton	90,900	H	3
Tewkesbury	84,100	G	4
Torbay	117,900	I	3
Trafford§	205,700	E	4
Trowbridge (West Wiltshire district)	103,000	H	4
Truro (Carrick district)	78,300	I	1
Wakefield	306,300	D	4
Walsall	255,600	F	4
Warrington	177,500	E	4
Warwick	116,800	F	4
Wigan§	301,900	E	3
Winchester	93,700	H	5
Wolverhampton	239,800	F	4
Woodspring§	173,900	H	4
Worcester	76,200	G	4
York	102,200	D	5

*Unitary authorities are not labeled on the map, but their boundaries are marked. Only a selection of unitary authorities are listed in the index.
†Populations are for districts, which may include rural areas as well as the city or town. The British government does not report populations for individual cities and towns.
‡*World Book* estimate based on 1991 census figures. Brighton and Hove merged in December 2000.
§Does not appear on map, key shows general location.
Sources: 1991 census preliminary figures; 1985 official estimates.


England
political map
National Park (N.P.)
National boundary
County or unitary authority boundary*
Expressway
Road
Railroad
National capital
Administrative center
Other city or town
WORLD BOOK map
*Names appear in red only for counties and Greater London, which is neither a county nor a unitary authority.
1
2
3
4
5
6
7
A
B
C
D
E
F
G
H
I
J
West Longitude 4°
North Latitude
North Latitude 50°
North
Scotland
Northern Ireland
IRELAND
Wales
ENGLAND
FRANCE
North Sea
Irish Sea
English Channel
Bristol Channel
St. George's Channel
North Channel
Cardigan Bay
Strait of Dover
Bay of the Seine
Bay of the Somme
CHANNEL TUNNEL
Colonsay
Jura
Islay
Mull of Oa
Sound of Jura
Inveraray
Helensburgh
L. Lomond
Dumbarton
Greenock
Tarbert
Renfrew
Glasgow
Bathgate
Largs
Hamilton
Motherwell
Stirling
Alloa
Glenrothes
Kirkcaldy
Dunfermline
Firth of Forth
St. Andrews
Fife Ness
Edinburgh
Dunbar
Musselburgh
St. Abb's Head
Penicuik
Peebles
Duns
Berwick-upon-Tweed
Holy Island (Lindisfarne)
Ardrossan
Brodick
Arran
Firth of Clyde
Kilmarnock
Lanark
Galashiels
Newtown St. Boswells
Belford
Campbeltown
Ayr
Cumnock
Maybole
Sanquhar
Hawick
Jedburgh
Alnwick
Mull of Kintyre
Moffat
Dalmellington
Girvan
NORTHUMBERLAND NATIONAL PARK
Northumberland
Cushendall
Ballantrae
Newcastleton
Bellingham
Blyth
New Galloway
Dumfries
Lockerbie
Newcastle upon Tyne
South Shields
Ryan
Wigtown
Castle Douglas
Hexham
Sunderland
Stranraer
Larne
Kirkcudbright
Solway Firth
Carlisle
Gateshead
Consett
Luce Bay
Newtownabbey
Bangor
Belfast
Lisburn
Strangford Lough
Mull of Galloway
Burrow Head
Maryport
Keswick
Cumbria
Ullswater
Penrith
Crook
Durham
Hartlepool
Whitehaven
Stockton-on-Tees
Middlesbrough
Whitby
Barnard Castle
Darlington
St. Bees Head
LAKE DISTRICT N.P.
Kirkby Stephen
Richmond
NORTH YORK MOORS N.P.
Point of Ayre
Ramsey
Kirk Michael
Downpatrick
Newcastle
Windermere
Northallerton
North Yorkshire
Scarborough
Isle of Man
YORKSHIRE DALES N.P.
Thirsk
Pickering
Malton
Dundrum Bay
Ulverston
Kirkby Lonsdale
Ripon
Bridlington
Flamborough Head
Douglas
Barrow in Furness
Morecambe
Kilkeel
Calf of Man
Castletown
Isle of Walney
Lancaster
Knaresborough
Bridlington Bay
Morecambe Bay
Skipton
Harrogate
York
Great Driffield
Fleetwood
Clitheroe
Beverley
Blackpool
Lancashire
Blackburn
Bradford
Leeds
Selby
Kingston upon Hull
Halifax
Goole
Skerries
Ribble
Preston
Wakefield
Humber
Spurn Head
Southport
Rochdale
Huddersfield
Lambay I.
Wigan
Bolton
Barnsley
Doncaster
Scunthorpe
Grimsby
Carmel Head
Amlwch
Liverpool Bay
Liverpool
Salford
Oldham
Manchester
St. Helens
Rotherham
Gainsborough
Louth
Holyhead
Anglesey
Conwy Bay
Birkenhead
Mersey
Warrington
Stockport
Sheffield
Mablethorpe
Holy I.
Bray
Colwyn Bay
Northwich
PEAK DISTRICT N.P.
Worksop
Lincoln
Horncastle
Bangor
Denbigh
Chester
Macclesfield
Chesterfield
Skegness
Wicklow
Caernarfon Bay
Caernarfon
Cheshire
Congleton
Derbyshire
Mansfield
Newark-upon-Trent
Wrexham
Crewe
Stoke on Trent
Matlock
Nottinghamshire
Lincolnshire
Boston
Gibraltar Point
Ffestiniog
Newcastle-under-Lyme
Belper
Porthmadog
SNOWDONIA N.P.
Whitchurch
Staffordshire
Derby
Nottingham
Sleaford
The Wash
Hunstanton
Cromer
Pwllheli
Bala
Burton upon Trent
West Bridgford
Grantham
Aylsham
Tremadoc Bay
Oswestry
Loughborough
Spalding
King's Lynn
Norfolk
Great Yarmouth
Trwyn Cilan
Dolgellau
Stafford
Barmouth
Welshpool
Shrewsbury
Telford
East Dereham
Norwich
Tywyn
Wolverhampton
Walsall
Glenfield
Leicester
Stamford
Wymondham
Lowestoft
Shropshire
Leicestershire
Market Harborough
Peterborough
Great Ouse
Bungay
Newtown
Bishop's Castle
Dudley
Birmingham
Cambridgeshire
Thetford
Aberystwyth
Stourbridge
Solihull
Coventry
Kettering
Ely
Southwold
Llandrindod Wells
Ludlow
Bromsgrove
Worcestershire
Warwickshire
Northamptonshire
Huntingdon
Newmarket
Suffolk
Aberaeron
Warwick
Northampton
Cam
Bury St. Edmunds
Aldeburgh
Leominster
Worcester
Avon
Stratford-upon-Avon
Cambridge
Cardigan
Builth Wells
Great Malvern
Towcester
Bedford
Haverhill
Ipswich
Fishguard
Llandovery
Hereford
Evesham
Banbury
Bedfordshire
Biggleswade
Saffron Walden
Harwich
St. David's Head
PEMBROKESHIRE COAST N.P.
Brecon
Ross on Wye
Tewkesbury
Bicester
Milton Keynes
Letchworth
Bishop's Stortford
Colchester
The Naze
Carmarthen
BRECON BEACONS N.P.
Cheltenham
Luton
Hertfordshire
St. Brides Bay
Haverfordwest
Merthyr Tydfil
Ebbw Vale
Gloucester
Oxfordshire
Aylesbury
St. Albans
Hertford
Essex
Clacton-on-Sea
Milford Haven
Pembroke
Llanelli
Pontypool
Gloucestershire
Oxford
Buckinghamshire
Chelmsford
Carmarthen Bay
Cwmbran
Stroud
Cirencester
Thames
Abingdon
Watford
Epping
Basildon
St. Govan's Head
Swansea
Port Talbot
High Wycombe
Greater London
Southend-on-Sea
Cardiff
Newport
Swindon
Henley-on-Thames
Maidenhead
London
Swansea Bay
Bridgend
Bristol
Chippenham
Windsor
WINDSOR CASTLE
Kingston upon Thames
Gravesend
Margate
Reading
Newbury
Chatham
Gillingham
Ramsgate
Weston-super-Mare
Bath
Trowbridge
Basingstoke
Woking
Surrey
Reigate
Maidstone
Canterbury
Frome
Wiltshire
Aldershot
Guildford
Tonbridge
Kent
Dover
Lundy I.
Ilfracombe
Minehead
Bridgwater Bay
Warminster
STONEHENGE
Andover
Haslemere
Tunbridge Wells
Folkestone
EXMOOR N.P.
Somerset
Crawley
Barnstaple Bay
Barnstaple
Bridgwater
Glastonbury
Salisbury
Winchester
Cuckfield
Hampshire
West Sussex
East Sussex
Rye
Bideford
Wellington
Taunton
Shaftesbury
Lewes
Tiverton
Yeovil
Sherborne
Southampton
Chichester
Hastings
Bude
Devon
Exe
Chard
Dorset
Portsmouth
Worthing
Brighton and Hove
Eastbourne
Boulogne-sur-Mer
Bude Bay
Okehampton
Bridport
Poole
Lymington
Solent
Beachy Head
Exeter
Lyme Regis
Dorchester
Bournemouth
Newport
Launceston
DARTMOOR N.P.
Exmouth
Weymouth
Swanage
Poole Bay
Isle of Wight
Le Touquet
Newton Abbot
Lyme Bay
Bill of Portland
Weymouth Bay
St. Catherine's Point
Bodmin
Newquay
Cornwall
Torbay
Saltash
Plymouth
Dartmouth
Redruth
Truro
Plymouth Sound
Start Point
Penzance
Falmouth
ST. MICHAEL'S MOUNT
Mount's Bay
Lizard Point
St.-Valery
Dieppe
Penzance
Land's End
Isles of Scilly
Alderney
Channel Islands
Cap de la Hague
Cherbourg
Fécamp
Neufchâtel
Le Havre
Seine
Rouen
0
50
100
150
200
250 Miles
300
350
400 Kilometers

of the English language, including the history of its development, see **English language.**

Many English words have different meanings in England than they have in the United States. In England, for example, freight cars are *trucks* and trucks are *lorries.* Gasoline is called *petrol.* Elevators are *lifts,* and cookies are called *biscuits.*

The way English is spoken varies throughout England. For example, people in the western part of England speak with a flatter accent and pronounce the letter *r* more clearly than do people in other areas. In east Yorkshire, in the northern part of England, the accent is soft and rather musical. People in the East End section of London speak a harsh dialect called *cockney.*

Way of life

City life. About 95 percent of the English people live in urban areas. The city centers are business and entertainment districts with modern buildings. They are crowded with shoppers, office workers, and people going to restaurants, theaters, and other places of relaxation and entertainment. On the edges of the cities lie suburban areas of well-kept brick houses with neat gardens. Gardening is a favorite hobby of the English. Most of the houses are *detached* (separate) or *semidetached* (two houses sharing a common wall).

Areas of substandard housing lie between the central business districts and the outer suburbs of many English cities, especially in northern England. Some of these areas consist of factories surrounded by blocks of *terraced houses* (identical houses in a row), which were built cheaply in the late 1800's. Many of the factories are abandoned or only partially used, and many of the houses are in poor condition. Some of the areas have apartment buildings called *council flats* that were built in the 1960's and 1970's by local authorities as public housing. Many of these buildings were built inexpensively, using poor construction methods, and have become run-down. Lack of housing and an increase in the number of homeless people are issues of concern in many cities in England. Other concerns in large urban areas include unemployment and problems resulting from the heavy use of automobiles, such as traffic congestion and air pollution.

Rural life. Only about 5 percent of the English people live in rural areas. The rural areas of England, where farming is an important activity, include much of Devon and Cornwall in southwestern England; a broad strip of land in eastern England around a bay of the North Sea called The Wash; and the northern Pennines mountains. The people live in isolated rural dwellings or in country villages or towns.

Much of southeastern England and the areas surrounding England's northern and central cities appear rural. But the economies of these areas are actually extensions of cities. Most of the workers who live in these areas commute to jobs in the nearby cities. Area residents often visit the cities for shopping, dining, and entertainment.

Food and drink. Traditional English cooking is simple. The English like roasted and grilled meats and use fewer spices and sauces than do other Europeans.

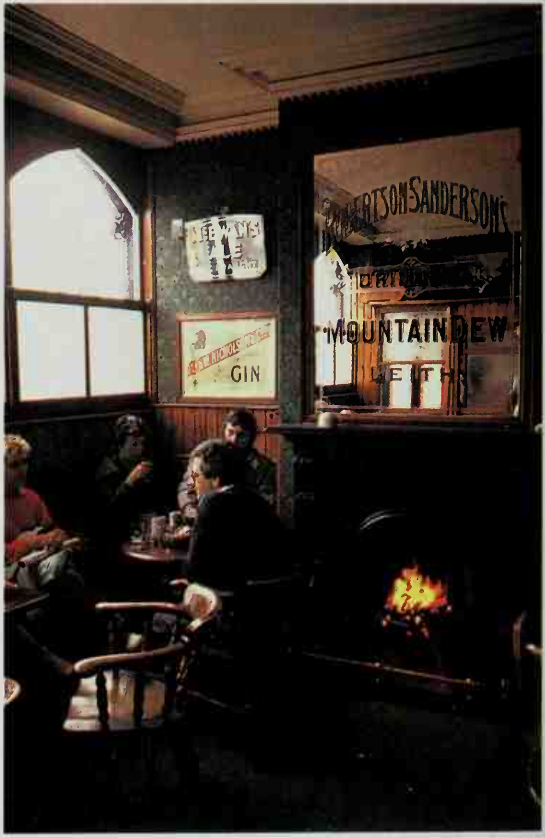
On Sunday, the midday meal, which is called *dinner,* traditionally consists of a *joint* (roast) of beef, pork, or lamb; roasted or boiled potatoes; a vegetable; and a *sweet* (dessert)—often fruit pie topped with hot custard sauce. *Yorkshire pudding,* a batter cake baked in meat fat, is often served with beef. Cabbage, Brussels sprouts, cauliflower, peas, and carrots are common vegetables because they are easily grown in England's climate.

Other popular English dishes include roast chicken, steak and kidney pie, shepherd's pie, and bangers and mash. *Steak and kidney pie* is a stew made of beef and kidneys and topped by a pastry crust. *Shepherd's pie* is a casserole of ground meat and mashed potatoes. *Bangers and mash* are thick sausages served with mashed potatoes.

The English also like fish, especially cod, Dover sole, haddock, herring, and plaice. *Fish and chips* is a favorite dish for lunch, the late afternoon meal called *tea,* or supper. It consists of fried fish and French fried potatoes and is sold at specialty shops throughout England.

The favorite alcoholic drink in England is beer, which includes lager, ale, bitter, and stout. Many English people also like Scotch whisky. A popular nonalcoholic drink in England is *squash,* which is made by adding water to a concentrate of crushed oranges or lemons.

Recreation. Many English people, like people elsewhere, spend the evening watching television. Others visit their neighborhood *pub* (public house). The pub, or



© Davies, ZEFA

A public house provides a place to meet friends, drink beer, enjoy a game of darts or dominoes, and chat. Such neighborhood taverns, called *pubs,* are important in English social life.

Cricket is one of England's most popular sports. Almost all towns and villages have cricket teams. The English have been playing cricket since at least the 1300's. The game became a major sport in England in the 1700's.

© Hugh Routledge, Robert Harding Picture Library

the local, as many people call it, is an important part of social life in England. At a pub, people may drink beer or other beverages, talk with friends, or play a game of darts or dominoes.

Many English people enjoy sports and outdoor activities, and they have many opportunities to participate in and watch organized sports. Others enjoy simply taking long hikes through the woods or countryside or working in their gardens.

England's most popular organized sport is *football,* the game Americans call soccer. During the football season, which lasts from August to May, about 20 million spectators watch the games. Millions of English people bet on the results of each week's football games by filling out *pools coupons.* The chances of winning are small, but winners have collected large amounts of money. At the end of the season, two teams battle for the Football Association Cup. International matches are held in England throughout the season.

Cricket has been popular in England for hundreds of years. It is played by two 11-member teams using bats and a ball. The English probably began playing cricket as early as the 1300's. Today, almost all towns and villages have cricket teams. Highlights of the cricket season are the international competitions called *test matches* between a team representing England and a team from Australia, India, New Zealand, Pakistan, Sri Lanka, or the West Indies.

Rugby, a game that uses an oval ball, is played in England from late summer to late spring. People of all ages, but especially older people, enjoy *bowls,* a sport similar to bowling. There are thousands of bowls clubs in England. Other favorite sports include golf, horse racing, rowing, sailing, swimming, and tennis.

Hunting, horseback riding, fishing, and shooting are popular in the English countryside. Some wealthy people shoot game birds such as grouse, partridge, pheasant, snipe, and woodcock. Fox hunting, a traditional English sport in which hunters on horses follow a pack of hounds chasing a wild fox, has also been popular among the wealthy. However, many oppose fox hunting.

Education. All English children between the ages of 5 and 16 must attend school. About 90 percent of the students go to schools supported entirely or partly by public funds. The rest attend private schools. The Department of Education and Science and local education authorities supervise England's school system.

For many years, every child had to take an *11-plus* examination after attending elementary school from ages 5 through 11. This test determined which of three specialized high schools—*grammar, secondary-modern,* or *technical*—a child would attend from ages 11 through 16. Grammar schools prepared students for college entrance. Secondary-modern schools provided a general education. Technical schools offered vocational training. But in the 1960's and 1970's, the English educational system gradually changed. Most grammar, secondary-modern, and technical schools have been replaced by *comprehensive* schools. These schools provide all three types of education.

England's *public schools* are actually private schools. But they are called *public schools* because the earliest of them were established for the children of the middle classes. Most of the public schools are boys' boarding schools. Students generally attend these schools from about ages 11, 12, or 13 up to 18 or 19. The leading public schools include Charterhouse, Eton, Harrow, St. Paul's, and Winchester. Such schools traditionally have helped train students for high-ranking positions in the government, the Church of England, the armed forces, or the practice of law. To pass the difficult entrance examinations of the public schools, some young boys attend private *prep* (preparatory) schools from about age 5 to 11, 12, or 13.

Institutions of higher education in England include two of the most famous universities in the world, Oxford

Hiking through the countryside is a favorite English pastime. A number of people take walking vacations. These backpackers are making their way through Dartmoor, in southwestern England.

© M. H. Black, Robert Harding Picture Library

and Cambridge. The largest traditional university in England is the University of London, which has about 60,000 resident students. England's Open University has about 195,000 students. It has no regular classrooms. Instruction is carried out through radio, television, correspondence, audiotapes, and videocassettes.

Religion. The Church of England, or Anglican Church, is the official church in England. The British monarch must belong to it and is its worldly head. All other English people may worship as they choose. The spiritual head of the Church of England is the archbishop of Canterbury, who is known as the *primate of all England.* The archbishops of Canterbury and York and 24 bishops have seats in the House of Lords. This gives the Church of England an official link with the British government.

The Church of England has about 27 million members, but most of them do not attend services. The Episcopal Church in the United States developed from the Church of England.

Many English people belong to other Protestant churches, which are called *Free Churches.* The largest Free Churches include the Baptist, Methodist, and United Reformed churches.

There are about 4 million Roman Catholics in England. The Catholic Church is headed by the archbishop of Westminster. England also has about 325,000 Jews, one of the largest Jewish populations in Europe.

The arts. The English enjoy motion pictures, plays, and concerts. London is the center of English music and drama. But Birmingham and other major cities also have a growing number of music and theater companies.

England has a history of producing outstanding artists. It has been the birthplace of many noted architects, painters, and composers. But its greatest artists have probably been writers. Geoffrey Chaucer, Charles Dickens, William Shakespeare, and many other English authors wrote masterpieces of literature.

English architects have developed many different styles over the years. The Norman style began after the Norman Conquest of 1066. Buildings designed in the Norman style have heavy columns and semicircular arches. The Tudor style became popular for houses in the late 1500's, during the reign of Queen Elizabeth I.

George Rodger, Magnum, courtesy National Geographic Society

Canterbury Cathedral is the church of the archbishop of Canterbury, the spiritual head of the Church of England.

Tudor was the family name of the queen. Characteristics of the Tudor style include flat arches; many windows, gables, and chimneys; and timber frames filled in with brick and plaster.

During the 1600's, two of England's greatest architects were Inigo Jones and Sir Christopher Wren. Jones designed the Queen's House in Greenwich and remodeled St. Paul's Cathedral in London. Wren rebuilt St. Paul's and many other churches after they were destroyed by the Great Fire of London in 1666. Georgian architecture, which began during the 1700's, uses much brick and stone and has a simple, balanced design.

For hundreds of years, English painters followed the styles of other European artists. But during the 1700's, such painters as Thomas Gainsborough, William Hogarth, and Sir Joshua Reynolds began to develop their own individual styles. During the 1800's, John Constable and Joseph Turner produced beautiful landscapes. Important English painters of the 1900's included Duncan Grant, David Hockney, Paul Nash, Ben Nicholson, John Piper, and Graham Sutherland.

The English have always loved music, and many of their old folk songs are still sung throughout the English-speaking world. During the 1500's and early 1600's, such composers as Thomas Tallis and William Byrd wrote excellent church music. Henry Purcell, who lived in the late 1600's, is considered one of England's greatest classical composers. In the 1870's and 1880's, Sir William S. Gilbert and Sir Arthur Sullivan wrote many popular satirical operettas. Leading English composers of the 1900's included Benjamin Britten, Frederick Delius, Sir Edward Elgar, Gustav Holst, Ralph Vaughan Williams, and Sir William Walton. Two English groups, the Beatles and the Rolling Stones, had enormous influence on the development of rock music.

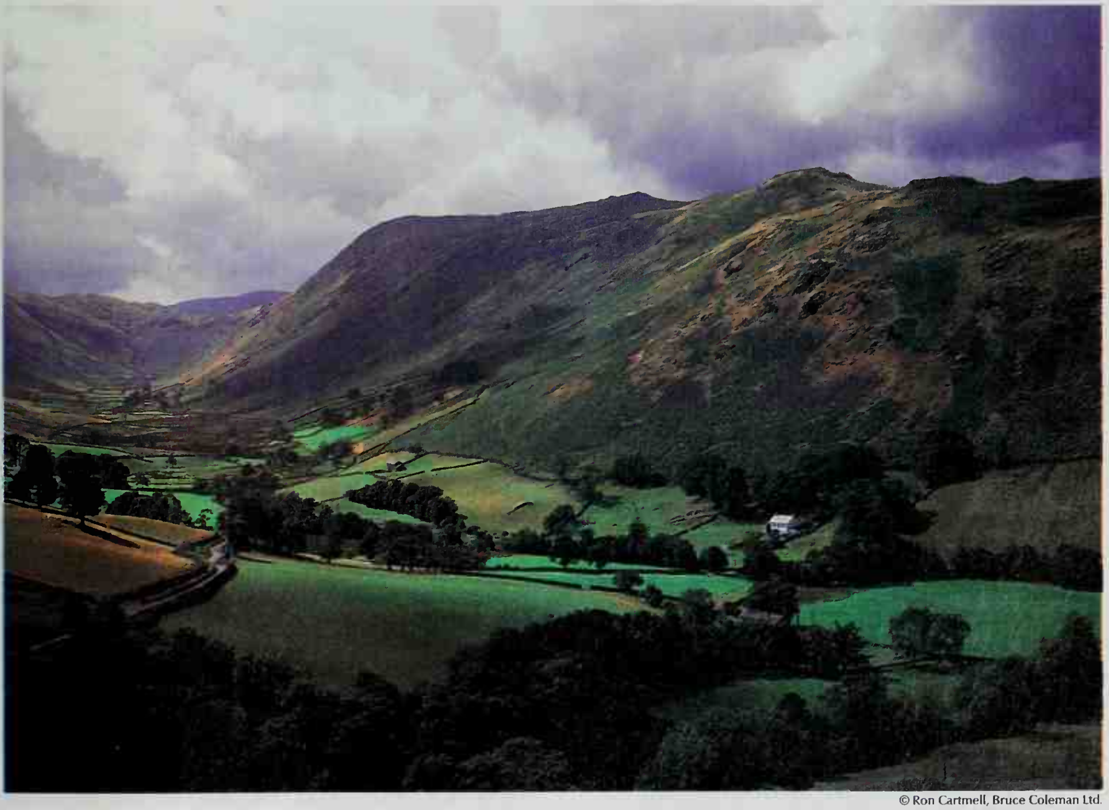
English furniture makers were the best in Europe during the 1700's. Furniture collectors today prize the beautifully designed works of Thomas Chippendale, George Hepplewhite, and Thomas Sheraton. Also during the 1700's, Josiah Wedgwood and Josiah Spode produced lovely chinaware. Wedgwood and Spode pottery is still one of the United Kingdom's important exports.

For more information, see the separate articles on **Architecture; Classical music; Drama; English literature; Furniture; Painting; Rock music;** and **Theater.**

The land

England, Scotland, and Wales occupy the island of Great Britain. The River Tweed and the Cheviot Hills form England's northern border with Scotland. Wales lies west of England. The Irish Sea separates England and the island of Ireland, and the English Channel and the North Sea divide England from Europe's mainland.

Land regions. England has three main land regions. They are the Pennines, the Southwest Peninsula, and the English Lowlands.



© Ron Cartmell, Bruce Coleman Ltd.

The Pennine Chain is a long line of uplands that runs like a backbone through northern and central England. The chain is rich in a number of minerals, and it is an important recreational area.

Robert Harding Picture Library

The Lake District is one of England's most scenic areas. It is a region of clear, quiet lakes and low mountains. The Lake District lies in northwestern England, west of the Pennine Chain.

© Telegraph Colour Library from FPG

The white cliffs of Dover rise on the southeastern coast of England. The cliffs are composed of chalk. They border the Strait of Dover, a narrow channel that separates England from France.

The Pennines are England's main mountain system, often called the *backbone of England.* They extend from the Scottish border about halfway down the length of England. They are also known as the *Pennine Chain* or *Pennine Hills.* The Pennines are rich in coal. West of the Pennines lies the Lake District, an area known for its beautiful mountain scenery and its many lakes. The highest point in England, 3,210-foot (978-meter) Scafell Pike, is in the Lake District.

The Southwest Peninsula consists of a low plateau with highlands rising above it. Several of the highlands are composed of granite. Near much of the coast, the plateau ends sharply in cliffs that tower above the sea. The westernmost point in England, Land's End, and the southernmost point in the British Isles, Lizard Point, are both on the peninsula.

The English Lowlands cover all of England outside the regions of the Pennines and the Southwest Peninsula. The Lowlands have most of England's farmable land, industry, and people.

The rich plains of Lancashire lie in the northwestern part of the region, and those of Yorkshire lie in the northeastern part. A large plain called the Midlands occupies the center of the English Lowlands. England's chief industrial cities are in the Midlands. South of the Midlands, a series of hills and valleys crosses the land to the valley of the River Thames.

Most of the land north of the Thames and up to a bay

Physical features

Avon, River	D	3
Barnstaple Bay	D	2
Berkshire Downs	D	3
Bill of Portland (peninsula)	E	3
Bodmin Moor	E	2
Bristol Channel	D	2
Broads, The (region)	C	5
Cam, River	D	4
Cheviot, The (peak)	A	3
Cheviot Hills	A	3
Chiltern Hills	D	4
Cotswold Hills	D	3
Cumbrian Mountains	B	2
Dartmoor (moor)	E	2
Dee, River	C	2
Dungeness (cape)	E	4
East Anglia (region)	C	4
Eden, River	A	2
English Channel	E	3
Exmoor (moor)	D	2
Fens, The (region)	C	4
Falmouth Bay	E	2
Great Holme Fen	C	4
Hampshire Downs	D	3
Holy Island	A	3
Humber, River	B	4
Isle of Walney	B	2
Isle of Wight	E	3
Isles of Scilly	E	1
Kennet, River	D	3
Lake District	B	2
Lancashire Plain	B	3
Land's End (point)	E	1
Lincoln Wolds	C	4
Liverpool Bay	D	2
Lizard Point	E	2
Lyme Bay	E	2
Mersey, River	C	3
Midlands (region)	C	3
Morecambe Bay	B	2
Mouth of the Thames	D	4
North Downs	D	4
North York Moors	B	3
Ouse, River	B	3
Peak District	C	3
Pennines (mountains)	A	3
Salisbury Plain	D	3
Scafell Pike (peak)	B	2
Severn, River	C	3
Sherwood Forest	C	3
Solent, The (channel)	E	4
Solway Firth	A	2
South Downs	E	4
Strait of Dover	D	5
Tees, River	B	3
Thames, River	D	4
Trent, River	B	4
Tweed, River	A	3
Tyne, River	A	3
Vale of York	B	3
Wash, The (bay)	C	4
Weald, The (region)	D	4
Welland, River	C	4
Windermere (lake)	B	3
Wye, River	C	4
Yorkshire Wolds	B	4

of the North Sea called The Wash is low and flat. This area has rich farmland. A great plain called The Fens borders The Wash. South of the Thames, long, low lines of hills called *scarplands* cross the land. Between the scarplands are lowlands of clay. The scarplands consist of layers of chalk and other forms of limestone. Along the English Channel, the hills drop sharply and form steep cliffs. The most famous are the white cliffs of Dover.

Rivers and lakes. England's rivers flow from the central uplands to the seas. The rivers that flow east to the North Sea include the Tees, Thames, Tyne, and a group of rivers that join and form the Humber. The rivers that flow west into the Irish Sea and the Bristol Channel include the Mersey, Dee, Severn, and Avon. Several shorter streams flow south from the uplands into the English Channel.

The Thames is the longest river entirely in England. It is 215 miles (346 kilometers) long. The 220-mile (354-kilometer) Severn is longer than the Thames. Most of it is in England, but part is in Wales. England's third longest river, the Trent, is 170 miles (274 kilometers) long. All three rivers are navigable for part of their length and are connected by canals. England has more than 2,000 miles (3,200 kilometers) of inland waterways. Many of England's rivers empty into broad inlets that make excellent harbors. London, Liverpool, and other English ports are on or near such inlets.

England's largest natural lakes are in the Lake District, where 16 lakes lie within a circle about 30 miles (48 kilometers) in diameter. The largest lake, Windermere, is about 10 $\frac{1}{2}$ miles (17 kilometers) long and about 1 mile (1.6 kilometers) wide at its widest point.

Islands. England has a number of offshore islands. One of the most important is the lovely Isle of Wight, near the southern coast. The colorful Isles of Scilly lie off Land's End in southwestern England. The Isle of Man, in the Irish Sea, and the Channel Islands, in the English Channel, are British crown dependencies but are not part of England. These islands are largely self-governing, though the British government takes responsibility for their defense and foreign affairs.

For more information about the geography of England, see *The land* section of **United Kingdom.** For information on England's climate, see the *Climate* section of **United Kingdom.**

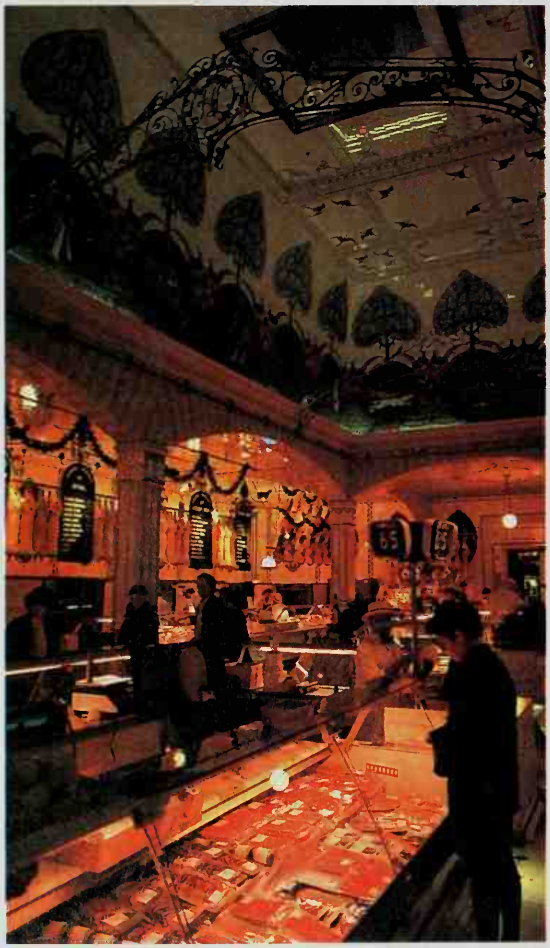
Economy

England has been a leader in manufacturing since the Industrial Revolution began there in the 1700's. England

produces most of the United Kingdom's industrial and farm products. England's ideal location on the busy North Atlantic shipping lanes—and its many excellent harbors—have helped make it Britain's center of trade. Service industries are also an important part of England's economy.

Service industries employ about 70 percent of English workers. England's most important service industries include banking and insurance. London is an international financial center. Its major financial institutions include the Bank of England, Britain's national bank; the London Stock Exchange, one of the world's busiest stock exchanges; and Lloyd's, the famous worldwide insurance society. Other important service industries in England include tourism, transportation and communications, education, and health care.

Manufacturing provides jobs for about 20 percent of the work force. Most of the United Kingdom's exports are goods manufactured in England. For many years, almost all of England's factories were built near coal fields, close to their source of power. Today, electricity, oil, and gas are being used more and more. As a result, many new industries have developed around London and in the southeastern section of England, where there is little coal.



© J. Reznicki, The Stock Market

Harrods, a well-known English department store, includes a meat market with a cathedral ceiling. Wholesale and retail trade and other service industries employ most English workers.

England's chief manufactured products include beverages, chemicals, clothing, electronic equipment, engines for military aircraft, fabricated steel products, footwear, leather goods, paper, processed foods, tobacco, and woolen cloth and other textiles. England is also a leader in printing and publishing.

Agriculture and fishing. England's chief agricultural products include barley, cattle, chickens and eggs, fruits, milk, potatoes, sheep, sugar beets, and wheat. England's shallow coastal waters provide excellent fishing. Cod, haddock, and mackerel are the principal fishes caught in English waters. The main fishing ports are Hull on the North Sea coast and Fleetwood on the Irish Sea coast.

Mining. England ranks as a major coal producer. The largest coal fields extend along both sides of the Pennine Chain into the Midlands. Coal output has been declining steadily, however, because of the increased use of oil, natural gas, and nuclear power. England's coal industry has also suffered competition from lower-priced coal imported from Poland and South Africa.

Oil deposits and fields of natural gas lie in the North Sea, east of the island of Great Britain. The United Kingdom began pumping natural gas from North Sea wells in 1967, and it began pumping petroleum from the sea in 1975. The production of natural gas and petroleum has increased rapidly since then and has greatly benefited England's economy.

England's iron ore production, which was once important to the steel industry, has declined. Most deposits of high-grade ore have been exhausted, and most of the ore that England uses has to be imported.

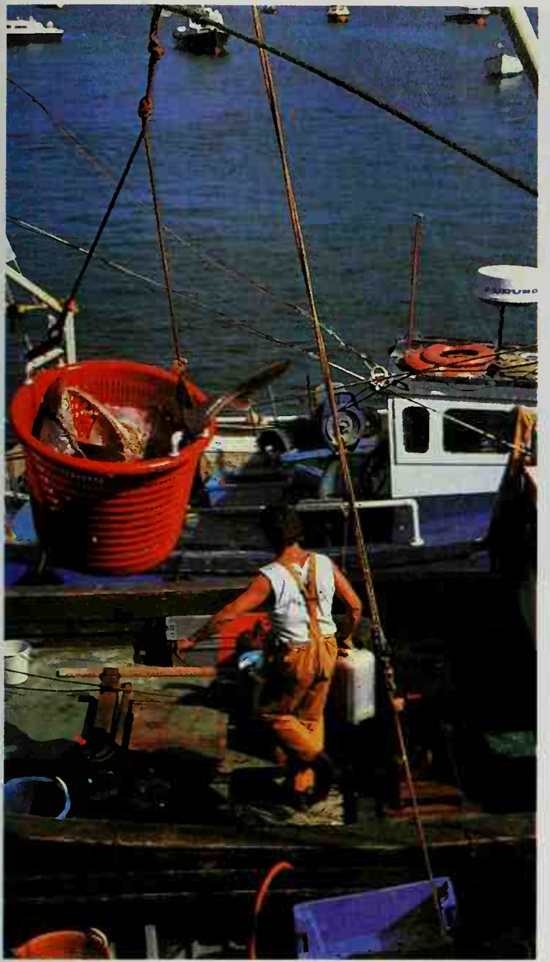
Southwestern England has fine china clay, which is used in making pottery. Southeastern England has deposits of chalk, which is used to make cement.

Transportation and communication. England has an extensive system of *motorways* (expressways) that link London with other major industrial centers. Roads and railroads carry passenger and freight traffic. England has dozens of ports of commercial significance. The most important are London, Tees and Hartlepool, Grimsby and Immingham, Southampton, and Liverpool. England also has a widespread inland waterway system, but these rivers and canals are more important for recreational boating than for transporting freight.

Ferry services and *hovercraft* (vehicles that ride over water on a cushion of air) carry passengers across the English Channel between England and France. In 1987, the United Kingdom and France began construction of a railroad tunnel beneath the English Channel. The tunnel was completed in 1994 (see **Channel Tunnel**).

England has approximately 80 daily newspapers. About 15 of them, including *The Sun, The Times,* and *The Daily Telegraph,* circulate throughout the United Kingdom.

The British Broadcasting Corporation (BBC), a public corporation, provides radio and television services. Other broadcasting services are controlled by the Radio Authority and the Independent Television Commission (ITC). The BBC has no commercials. It is financed chiefly


Adam Woolfitt, Robert Harding Picture Library

Fishing is an important economic activity in England. England's shallow coastal waters provide excellent fishing. This fishing boat is docked at St. Mary's, the largest island of the Isles of Scilly, which lie off England's southwestern coast.

by yearly license fees paid by television owners. Services controlled by the Radio Authority and the ITC broadcast commercials.

For more information on England's economy, see the *Economy* section of the **United Kingdom** article.

History

Scholars do not know when the first people arrived in what is now England. But they do know that prehistoric people lived in caves in the region during the Old Stone Age, which ended about 10,000 years ago. Scientists believe that the sea was lower at that time, and what is now the island of Great Britain was part of the European mainland.

By about 6000 B.C., Great Britain had become an island. In the mid-3000's B.C., people in England began to grow crops and raise cattle, pigs, and sheep. The knowledge of farming and livestock raising probably came from people who lived along the lower Rhine River in what are now Germany and the Netherlands and in present-day Brittany in northwestern France.

In the early 1000's B.C., people in England mined tin and made bronze tools. They also built large circular monuments with stones. Scholars believe these monuments were religious structures. Stonehenge, the most famous monument, still stands near Salisbury.

Historians are not certain when the Celtic language was first used in England, but it had been introduced there by about the mid-600's B.C. A form of Celtic called Brythonic was spoken throughout the island of Great Britain.

The Celts worshiped nature gods through priests called *Druids.* They used iron and mined tin. Celtic-speaking people probably brought the knowledge of ironmaking to England in the mid-600's B.C. from areas in what is now Austria. The Celts also made woolen cloth, which they dyed bright colors. They traded with the Gauls in what is now France and with Celtic tribes in Ireland.

The Roman conquest. In 55 B.C., the great Roman general Julius Caesar sailed across the English Channel from Gaul with a small force to explore England. He returned the next year with an invading army and defeated some of the Celts before returning to Rome.

In A.D. 43, the Roman emperor Claudius ordered Roman armies to invade Britannia, as the island was then called. The Romans easily conquered the Celtic tribes. In A.D. 61, the Roman forces put down a revolt led by Boadicea (or Boudicca), queen of a tribe of Britons called the Iceni. During the A.D. 80's, the Romans completed the conquest of the southern part of the island of Great Britain, including present-day England and

Important dates in England

A.D. 43	Roman armies invaded Britannia.
400's	Germanic tribes invaded England.
597	Saint Augustine of Canterbury brought Christianity to the people of southern England.
1066	Norman forces won the Battle of Hastings, and William the Conqueror became king of England.
1215	English barons forced King John to agree to Magna Carta.
1282-1283	England conquered Wales.
1295	Edward I called together the Model Parliament.
1314	Scotland assured its independence from England by winning the Battle of Bannockburn.
1337-1453	England fought the Hundred Years' War with France and lost most of its lands on the European mainland.
1455-1480's	Two royal families fought for the throne in the Wars of the Roses.
1534	At the urging of Henry VIII, Parliament made the king supreme head of the church in England.
1536	Henry VIII united England and Wales.
1588	An English fleet defeated the Spanish Armada.
1603	England and Scotland were joined in a personal union under one king, James I.
1642-1648	Supporters of the king fought supporters of Parliament in a civil war.
1649-1659	England became a commonwealth and then a protectorate.
1660	Parliament restored the monarchy in England.
1688	The Glorious Revolution ended James II's rule.
1689	Parliament passed the Bill of Rights.
1707	England and Wales were united politically with Scotland, forming a united kingdom of Great Britain. (For later dates, see **United Kingdom** [History]).

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Hadrian's Wall, built by the Romans in the A.D. 120's, protected England from northern raiders. It extended from Solway Firth to the North Sea. Parts of the wall, such as that above, still stand.

Wales. They were never able to completely subdue what is now Scotland.

The Romans made the part of the island under their control a province of their huge empire. They built camps and forts throughout the land and constructed roads to connect the camps. The most famous road, which became known as Watling Street, ran from Richborough, near Dover, to Chester and passed through the settlements that became Canterbury and London. The Romans also built walls and forts across northern England to protect the province from the warlike peoples of Scotland. The most famous of the walls was Hadrian's Wall, named after the Emperor Hadrian. It was built in the A.D. 120's and extended from Solway Firth to the mouth of the River Tyne.

England prospered under the Romans. Trade flowed along the Roman roads, and towns sprang up around the armed camps. London, then called Londinium, began to develop as a port city. During the Roman period, Christianity came to England. A number of items bearing Christian symbols and dating from the A.D. 300's have been found in various places in England. In addition, an early Christian chapel has been discovered in a Roman villa in Kent.

The Germanic invasions. The Roman soldiers left England in the early 400's to help defend Rome against barbarian invaders. With the Romans gone, the Britons could not protect themselves against invasion by people from Scotland called *Picts* and people from Ireland called *Scots.* But the greatest danger came from seafaring Germanic tribes, especially the Angles, Saxons, and Jutes. These tribes first raided the coast. In the mid-400's, they began to establish permanent settlements. The Jutes were probably the first tribe to land. They settled in southeastern England, in what is now the county of Kent, and in south-central England on the Isle of Wight and in what is now southern Hampshire. The Angles and Saxons followed the Jutes and set up kingdoms throughout southern and eastern England. The name *England* comes from the Anglo-Saxon words meaning the *Angle folk* or *land of the Angles.*

The Germanic tribes gradually pushed the Britons north and west. The Britons held out for a number of years under a tribal chief who may have been the inspiration for the King Arthur legends. However, the Britons were beaten repeatedly, until they held only the mountain areas of the extreme western and northern parts of England.

In 597, Saint Augustine of Canterbury traveled from France to Kent and converted Ethelbert, king of the Jutes, to Christianity. Christianity had died out in most of England as a result of the Germanic invasions. The Germanic invaders were not Christians. Augustine built a monastery near Canterbury. Canterbury eventually became the main religious center in England. Augustine's followers spread Christianity in southern and central England. Celtic missionaries, who had begun converting tribes in Scotland during the 500's, converted many people in northern England.

The Anglo-Saxon period. The Angles and Saxons soon became the most powerful tribes in England. Each tribe became divided into separate nations. The Saxons, who occupied much of southern England, were organized into East Saxons, Middle Saxons, South Saxons, and West Saxons. The Angles lived mainly in northern, central, and eastern England. Their nations were called Mercia, East Anglia, and Northumbria.

In time, the tribal nations developed into seven main kingdoms called the *Heptarchy.* These kingdoms were East Anglia, Essex, Kent, Mercia, Northumbria, Sussex, and Wessex. During the 600's and 700's, Northumbria and Mercia each controlled, in turn, the other six kingdoms. In the 800's, under King Egbert, Wessex became the last kingdom to control the Heptarchy.

Danish raiders began to attack England in the late 700's. During the 800's, they easily conquered all the Anglo-Saxon kingdoms except Wessex. Alfred the Great, the king of Wessex, resisted most of the attacks. In 886, he defeated the Danes and forced them to withdraw to the northeastern third of England. The area ruled by the Danes became known as the *Danelaw.*

Alfred was an effective ruler who made his territory a united country. He supported Christianity, encouraged education, and issued a code of laws. He also built a fleet of ships, established fortified towns, and reorganized the army to protect his kingdom from the Danes.

Alfred died in 899. During the early 900's, Alfred's successors reconquered the Danelaw. But in the late 900's, during the reign of King Ethelred II, Danish attacks resumed. In 1016, Canute, a brother of the king of Denmark, became king of England. Canute, like Alfred, ruled as a wise and just king until his death in 1035. Two of Canute's sons followed him on the throne before the old Anglo-Saxon dynasty was restored.

The last great Anglo-Saxon king was Edward the Confessor, son of Ethelred II. He ruled from 1042 until his death in 1066. Edward built the first church on the site of what is now Westminster Abbey in London.

The Norman Conquest. Edward the Confessor died without a direct heir to the throne. The English nobles chose Harold, Earl of Wessex, as king. But a French nobleman, William, Duke of Normandy, claimed that Edward had promised him the throne. Soon after Harold became king, William invaded England. His Norman knights killed Harold and defeated his forces in the historic Battle of Hastings on Oct. 14, 1066. On Christmas Day, William, who became known as William the Conqueror, was crowned king of England.

William I established a strong central government in England. He formed an advisory council, the *curia regis,* to help him govern. William appointed Norman nobles to the council and to other high positions. He kept some of the conquered land for himself and divided most of the rest among his Norman followers.

During William's reign, many cathedrals and castles were built. The construction of the Tower of London began. Shortly before his death in 1087, William ordered a survey conducted to determine how much land and other property there was in England, who held it, and what taxes and services the landholders owed the king for their property. The record of William's survey became known as the *Domesday Book* and is a rich source of information about medieval England.

Although most Anglo-Saxons became serfs under the Normans, they kept their language and many of their customs. Through the years, the differences between the Anglo-Saxons and the Normans gradually decreased. For example, the Normans spoke French at first. But eventually, their language blended with that of the Anglo-Saxons. In time, the Normans and Anglo-Saxons became a united people. The modern English language developed from their blended languages.

Struggles for power. During the late 1000's and early 1100's, a struggle developed in England between the kings and the nobles. The nobles tried to increase their own power. However, the kings wanted to keep supreme authority over the country. Similar disputes occurred in most other European nations. But in England, unlike in the other countries, the kings at first won the struggle.

In 1088, William II, son of William the Conqueror, put down a revolt of Norman barons. Henry I, William II's brother, became king in 1100. He was also determined to keep the nobles in check and, in fact, strengthened the king's control over the country. But civil war broke out after Stephen, William the Conqueror's grandson, became king in 1135. The nobles and religious leaders became almost independent during the conflict.

Henry II, Henry I's grandson, followed Stephen as king in 1154. He regained the power that Henry I had held, and he increased it. He kept the Norman tradition of a powerful king. But he combined the tradition with the Anglo-Saxon system of local rule and expanded the system of jury trials. Under the Anglo-Saxons, each local court had decided cases mainly on the basis of local laws and customs and earlier cases. Henry sent judges to all parts of England to administer the same laws throughout the land. The judges' decisions became

Detail of the Bayeux Tapestry (late 1000's), embroidery on linen by unknown artists; total length, 230 feet (70 meters); William the Conqueror Center, Bayeux, France (Barnaby's Picture Library, London)

The Battle of Hastings in 1066, pictured on the Bayeux Tapestry, ended with the defeat of the English by the Normans. The Norman leader, William the Conqueror, became king of England.

the basis for the English system of *common law*—that is, law that applied equally anywhere in England. Today, English common law is the basis of the legal system in the United Kingdom, the United States, Canada, and many other countries.

Henry II wanted to control the church in England. This led to a bitter and famous conflict between Henry and Thomas Becket, archbishop of Canterbury. The quarrel ended when four of Henry's knights killed Becket in 1170 while he was at prayer in his cathedral. The people were so angered by the murder that Henry granted many special rights to religious leaders.

Magna Carta. Henry II's son Richard I, who was called Richard the Lion-Hearted, reigned from 1189 to 1199. But he spent only six months of his reign in England. Richard went to the Holy Land to fight in a military campaign called the Third Crusade, and he fought a war with France. He forced the people to pay high taxes to support his armies.

During his absence, Richard left the government in the care of ministers, but his brother John plotted to gain power. John was cruel and treacherous. The legendary Robin Hood supposedly fought against John's officers. John became king after Richard's death in 1199. During his reign, John made enemies among the barons and religious leaders, lost much of the land England held in France, and quarreled with Pope Innocent III. In an attempt to reduce John's power, a group of barons and church leaders demanded reform and then rebelled. They forced John to agree to a settlement in 1215 that became known as *Magna Carta* (Great Charter). It placed the king under English law and limited his power.

The beginnings of Parliament. Parliament became important in the late 1200's, during the reign of John's grandson Edward I. Like earlier kings, Edward called meetings of leading nobles and church leaders to discuss government problems. But Edward enlarged the meetings to include knights from the shires, less important church leaders, and representatives of the towns. A meeting in 1295 became known as the *Model Parliament* because it set the pattern for later Parliaments. In 1297, Edward agreed not to collect certain taxes without the consent of the realm. He also strengthened the royal court system.

Edward I brought Wales under English control. His army conquered the Welsh in 1283 after killing their leader, the Prince of Wales, late in 1282. In 1284, Edward issued the Statute of Rhuddlan, which reorganized Welsh lands and placed them under the control of the king and English nobles. In 1301, Edward gave the title Prince of Wales to his son, who had been born in Caernarfon, Wales, and who later became Edward II. Since then, all male heirs to the throne, except Edward II's son, have received that title.

Edward I also tried to conquer Scotland. In 1296, he invaded the country and proclaimed himself king of Scotland. But the Scots rebelled continually. Edward II's disastrous defeat in the famous Battle of Bannockburn in 1314 assured Scotland's independence for more than 300 years.

England became an important center of learning during the 1200's. Oxford and Cambridge universities received royal charters, and students from many countries flocked to them. During the 1200's, England also produced two of the greatest thinkers of the Middle Ages, Roger Bacon and John Duns Scotus.

The Hundred Years' War broke out between England and France in 1337. It lasted until 1453. Edward II's son Edward III became king in 1327. His mother was the sister of three French kings. The war began in 1337, when the French king, Philip VI, declared he would take over lands held by Edward in France. Edward, in turn, formally claimed the French throne. The first important battle was fought in 1346 at Crécy, in France, where Edward won a brilliant victory over the French. His son Edward, who was called the Black Prince, won the next great English victory, at Poitiers in 1356.

In spite of England's victories, the war dragged on. The English people began to oppose the long war, and Parliament refused to approve the high taxes needed to support it. In 1381, a blacksmith named Wat Tyler led a peasants' revolt against forced labor and heavy taxation. Forces of King Richard II, a son of the Black Prince, put down the rebellion.

During the 1390's, Richard tried to undermine the power of Parliament. But he governed so badly that the country turned against him. In 1399, he was forced to *abdicate* (give up the throne). Parliament chose his rival, the Duke of Lancaster, to rule as Henry IV.

Henry IV spent much of his time fighting small wars against English nobles and paid little attention to the war with France. But his son Henry V gained popular support for continuing the Hundred Years' War.

Henry V won a great victory at Agincourt in 1415. He then forced the king of France to accept him as *regent* (ruler in place of the king) and heir to the French throne. After Henry died in 1422, the French disputed the English claim to the throne, and the war flared again. By 1428, the English had swept through northern France. But the tide turned in 1429, when French forces led by a young peasant woman, Joan of Arc, defeated the English army in the Battle of Orléans. French successes continued. By the time the war ended in 1453, the English held only the city of Calais.

Great advances in literature and education occurred in England during the Hundred Years' War. English poetry became important for the first time. William Langland wrote *The Vision of Piers Plowman,* one of the first major poems in English. Geoffrey Chaucer helped shape the English language with such works as *The Canterbury Tales.* In 1440, Henry V's son, Henry VI, established Eton College.

The Wars of the Roses. A struggle for the throne began to develop near the end of the Hundred Years' War. Henry VI of the House (family) of Lancaster had become king in 1422. He was a weak ruler, and the nobles of the House of York decided to overthrow him. The wars that resulted came to be called the Wars of the Roses because York's emblem was a white rose and Lancaster's a red rose. The wars began in 1455. Edward IV of York won the throne from Henry VI in 1461, but Henry won it back in 1470. In 1471, Edward again defeated Henry and became king. Henry was imprisoned in the Tower of London, where he died.

When Edward died in 1483, his two sons were still children. His brother, Richard of York, imprisoned the boys in the Tower of London and declared himself King

Detail of an illuminated manuscript (1300's) by an unknown artist; Bibliothèque Nationale, Paris

The Battle of Crécy, fought in France in 1346, was the first important battle of the Hundred Years' War. English troops, *left,* led by Edward III, defeated the French forces, *far left,* in this battle.

Richard III. Some historians believe he had the boys murdered. But there is no proof of such a crime, and no one knows what happened to the boys.

Soon after Richard became king, Henry Tudor claimed the throne as heir of the House of Lancaster. His forces killed Richard and defeated the Yorkists in the Battle of Bosworth Field in 1485. Many historians consider this battle as marking the wars' end. Other scholars view the Battle of Stoke, won easily by Henry in 1487, as the wars' final engagement.

Henry Tudor ruled as King Henry VII. In 1486, he helped ensure future peace by marrying Edward IV's daughter, and so uniting the houses of Lancaster and York.

Henry VII was a stern, clever ruler. He held strong control over the nobles, cooperated with Parliament, and respected the interests of England's growing middle class. He also strengthened England's position among other nations by arranging marriages between his daughter and James IV of Scotland and between his son Arthur and Catherine of Aragon of Spain. After Arthur died, the king arranged Catherine's marriage to his second son, Henry.

The English Reformation. Henry VIII inherited great wealth when he became king in 1509. His father, Henry VII, had been a thrifty ruler. Henry VIII was talented and popular, but he was also selfish and wasteful. He enjoyed luxury, sports, good food, and music.

Early in his reign, Henry VIII made Thomas Cardinal Wolsey, archbishop of York, responsible for much of the country's management. But then, Henry wanted to annul his marriage to Catherine of Aragon, the first of his six wives. Wolsey was unable to get the pope to dissolve the marriage, so in 1529, Henry took away Wolsey's authority. During the 1530's, Thomas Cromwell became Henry's chief adviser. In 1534, Henry had Parliament pass a law declaring that the king, not the pope, was supreme head of the church in England. These actions occurred while the Reformation, the religious movement that gave birth to Protestantism, was spreading across northern Europe.

Following Henry's actions, English church leaders made changes in Roman Catholic services that gradually led to the formation of the Church of England. A number of Henry's subjects who opposed him were imprisoned or executed for treason.

During Henry VIII's reign, England and Wales were finally united. The Welsh people had revolted against the English several times after Edward I had conquered Wales in the 1280's. But the Welsh gradually accepted the idea of union with England. In acts of 1536 and 1543, Henry joined both countries under one system of government.

Parliament passed more church reforms during the short reign of Edward VI, Henry's son. But in 1553, Edward's half sister Mary became queen. Mary was the daughter of Catherine of Aragon and was a Roman Catholic. As queen, she reestablished Catholicism as the state religion.

The reign of Elizabeth I is often called the Golden Age of English history. Elizabeth became queen in 1558 after Mary, her half sister, died. Elizabeth was a strong but cautious ruler who played her enemies off against one another. One of her first acts was to reestablish the Church of England.

Under Elizabeth, England advanced in many areas. Merchants formed a great trading company, the East India Company, in 1600. Sir Francis Drake, Sir Walter Ra-

leigh, and other daring English adventurers explored the West Indies and the coasts of North and South America. English literature flowered during Elizabeth's reign with the works of such great writers as Francis Bacon, Ben Jonson, Christopher Marlowe, Edmund Spenser, and—above all—William Shakespeare.

In 1588, England won a great sea battle against Spain, the most powerful nation in Europe. King Philip II of Spain built a huge fleet called the *Armada* to conquer England. But an English fleet led by Admiral Lord Howard of Effingham defeated the Armada.

The first Stuarts. After Elizabeth I died in 1603, her cousin James VI of Scotland inherited the English throne. James belonged to the House of Stuart, which had ruled Scotland since 1371. As king of England, he took the title of James I. Although England and Scotland became joined in a *personal union* under James, he ruled each country as a separate kingdom. During his reign, English colonists founded the Jamestown and Plymouth settlements in America.

The English people disliked James. He increased royal spending, went into debt, and raised taxes. He quarreled frequently with Parliament because he wanted to rule as an absolute monarch. He believed in the *divine right of kings*—that is, that kings got their right to rule from God, not from the consent of the people.

Under James's son, Charles I, the struggle between the king and Parliament became more intense. Three groups—Puritans, lawyers, and members of the House of Commons—united against the king. In 1628, Charles reluctantly agreed to the *Petition of Right,* a document that limited the power of the king. However, Charles had no intention of keeping the agreement.

The Civil War. Charles I did not call Parliament into session from 1629 to 1640. When Parliament finally met in 1640, it refused to grant the king any funds unless he again agreed to limit his power. Charles reacted angrily, and civil war broke out in 1642.

People who supported the king in the war were called *Royalists* or *Cavaliers.* Parliament's greatest supporters were the Puritans, who were called *Roundheads* because they cut their hair short. The Puritans closed the theaters, changed the structure of the Church of England, and forced many of their religious beliefs on the people. During the war, Oliver Cromwell emerged as a leader in the army and in Parliament. In 1646, Charles surrendered to Scottish troops, but the next year, they turned him over to the Roundheads. Attempts to negotiate a settlement between the king and Parliament failed. In 1647 and 1648, the army removed the more moderate members from Parliament. The remaining members set up a special court, which condemned Charles to death. He was beheaded in 1649.

Detail of enamel portrait (late 1700's-early 1800's) by Henry Bone from an original painting of the late 1500's; National Trust/Art Resource, NY

Queen Elizabeth I ruled England from 1558 until her death in 1603. Her reign is often called the Golden Age of English history because it was a time of great achievement.

The rulers of England

Name	Reign
Saxons	
***Egbert**	802-839
Ethelwulf	839-858
Ethelbald	858-860
Ethelbert	860-865?
Ethelred I	865?-871
***Alfred the Great**	871-899
Edward the Elder	899-924
Athelstan	924-939
Edmund I	939-946
Edred	946-955
Edwig	955-959
Edgar	959-975
Edward the Martyr	975-978?
Ethelred II	978?-1016
Edmund II	1016
Danes	
***Canute**	1016-1035
Harold I	1035-1040
Hardecanute	1040-1042
Saxons	
***Edward the Confessor**	1042-1066
***Harold II**	1066
Normans	
***William I**	1066-1087
***William II**	1087-1100
***Henry I**	1100-1135
***Stephen**	1135-1154
Plantagenet family	
***Henry II**	1154-1189
***Richard I**	1189-1199
***John**	1199-1216
Henry III	1216-1272
***Edward I**	1272-1307
***Edward II**	1307-1327
***Edward III**	1327-1377
***Richard II**	1377-1399
House of Lancaster	
***Henry IV**	1399-1413
***Henry V**	1413-1422
***Henry VI**	1422-1461
House of York	
***Edward IV**	1461-1470
House of Lancaster	
***Henry VI**	1470-1471
House of York	
***Edward IV**	1471-1483
***Edward V**	1483
***Richard III**	1483-1485
House of Tudor	
***Henry VII**	1485-1509
***Henry VIII**	1509-1547
***Edward VI**	1547-1553
***Grey, Lady Jane**	1553
***Mary I**	1553-1558
***Elizabeth I**	1558-1603
House of Stuart	
***James I**	1603-1625
***Charles I**	1625-1649
Commonwealth	
***Long Parliament**	1649-1653
Protectorate	
***Oliver Cromwell**	1653-1658
Richard Cromwell	1658-1659
House of Stuart	
***Charles II**	1660-1685
***James II**	1685-1688
***William III**	1689-1702
and *Mary II	1689-1694
***Anne**	1702-1714

(For monarchs after 1714, see United Kingdom.)

*Has a separate article in *World Book.*

The trial of Charles I in 1649, after England's Civil War, resulted in a death sentence for the king. After Charles was beheaded, England became a republic called the Commonwealth of England.

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After Charles's execution, England became a republic called the Commonwealth of England. A committee of Parliament ruled the country. Cromwell ended the Commonwealth of England in 1653 by forcibly disbanding the Long Parliament. The Parliament was called *Long* because part of it had been meeting since 1640. England then became a dictatorship called the Protectorate, with Cromwell as *lord protector.* During his rule, Cromwell brought Scotland and Ireland under the control of England. His armies swept through both countries and put down all resisting forces.

The Restoration. Oliver Cromwell died in 1658, and his son Richard was named lord protector. But Richard could not handle the affairs of government. In addition, the people were dissatisfied with the Protectorate and wanted a monarchy again. George Monck, a general who had served under Oliver Cromwell, overthrew the government in 1660. A new Parliament, elected in 1660, restored the monarchy under Charles II, the son of Charles I.

Under Charles II, Parliament kept most of the powers it had won, and authority was divided between the king and Parliament. Charles died in 1685, and his brother became King James II. James, a Roman Catholic, wanted to restore Catholicism and absolute monarchy in England. The people disliked his ideas but put up with him. They expected James's Protestant daughter, Mary, to become queen after he died. Above all, they did not want another civil war. But when James had a son, people realized the restoration of Catholicism would be permanent. Leading politicians invited William of Orange, Mary's husband and ruler of the Netherlands, to invade England with Dutch forces and restore English liberties. In 1688, William landed in England. James fled to France and gave up his throne in what is called the Glorious Revolution.

In 1689, William and Mary became joint rulers of England after accepting what became known as the Bill of Rights. This document assured the people certain basic civil rights. In addition, the Bill of Rights made it illegal for the king to keep a standing army, to levy taxes without Parliament's approval, or to be a Roman Catholic.

War with France. During the late 1660's, France became the strongest nation on the European mainland. William III had fought against France when he ruled the Netherlands. As king of England, he made alliances with other countries to keep France from growing even more powerful. William died in 1702. His wife's sister, Anne, who was also a daughter of James II, became queen. In 1701, the War of the Spanish Succession had broken out, with England and most other European countries joining forces against France and Spain. The allied armies, led by England's Duke of Marlborough, defeated France. Under the peace treaty, signed at Utrecht in 1713, England won Newfoundland, Nova Scotia, and the territory around Hudson Bay from France, and Gibraltar and the island of Minorca from Spain.

The Augustan Age. During Queen Anne's reign, literature reached a height that many scholars considered similar to that reached in ancient Rome under Emperor Augustus. For this reason, her reign is said to mark the start of the Augustan Age. The literary masters of the period included Joseph Addison, Alexander Pope, Richard Steele, and Jonathan Swift. During Anne's reign, England's commercial prosperity also continued to grow, and Parliament won unquestioned control over the monarchy.

In 1707, the Act of Union joined the Kingdom of England and Wales with the Kingdom of Scotland to form a "united kingdom of Great Britain." The history of England then became part of the history of the United Kingdom. For the story of the United Kingdom, see **United Kingdom.**

Peter R. Mounfield, Anthony Sutcliffe, and Rodney Barker

Related articles in *World Book.* See **United Kingdom** and its list of *Related articles.* See also the following articles:

Biographies

See the biographies of the rulers whose names are marked by an asterisk in the table *The rulers of England* with this article. See also the following biographies:

Bacon, Francis
Bacon, Roger
Baffin, William
Becket, Saint Thomas
Boadicea
Boleyn, Anne
Buckingham, Duke of
Burghley, Lord
Cabot (John; Sebastian)
Calvert, George
Catherine of Aragon
Cromwell, Thomas
Drake, Sir Francis
Duns Scotus, John
Edward (the Black Prince)
Frobisher, Sir Martin
Gilbert, Sir Humphrey
Grenville, Sir Richard
Guy of Warwick
Hawkins, Sir John
Hudson, Henry
John of Gaunt
Laud, William
Marlborough, Duke of
Monck, George
Montfort, Simon de
More, Saint Thomas
Pym, John
Raleigh, Sir Walter
Russell, Lord John
Russell family
Strafford, Earl of
Warwick, Earl of
Wolsey, Thomas Cardinal

Cities and towns

Bath
Birmingham
Brighton and Hove
Bristol
Cambridge
Canterbury
Coventry
Dover
Durham
Glastonbury
Hull
Leeds
Leicester
Lincoln
Liverpool
London
Manchester
Newcastle upon Tyne
Nottingham
Oxford
Plymouth
Portsmouth
Salisbury
Sheffield
Southampton
Stoke-on-Trent
Stratford-upon-Avon
Winchester
York

Physical features

Avon, River
Bristol Channel
Dover, Strait of
English Channel
Humber, River
Irish Sea
Land's End
Mersey, River
Pennine Chain
Severn, River
Thames, River
Wight, Isle of
Windermere

Colleges, schools, and universities

Cambridge University
Charterhouse
Eton College
Harrow School
London, University of
Oxford University
Rugby School
Westminster School
Winchester College

Battles and wars

Agincourt, Battle of
Bannockburn, Battle of
Crécy, Battle of
Crusades
Hastings, Battle of
Hundred Years' War
Poitiers, Battle of
Succession wars (The War of the Spanish Succession)
Wars of the Roses

Important documents

Anglo-Saxon Chronicle
Bill of rights
Domesday Book
Magna Carta
Petition of Right

Peoples

Angles
Anglo-Saxons
Celts
Jutes
Normans
Saxons
Vikings

History

Cabal
Coffee house
Colonial life in America (Why the colonists came to America)
Coronation
Divine right of kings
Druids
East India Company
Glorious Revolution
Gunpowder Plot
Hampton Court Conference
Lancaster
Levellers
Long Parliament
Model Parliament
New England, Dominion of
Norman Conquest
Plymouth Colony
Plymouth Company
Prince of Wales
Puritans
Reformation (In England)
Restoration
Roman walls
Rump Parliament
Runnymede
Rye House Plot
Spanish Armada
Star Chamber
Stonehenge
Stuart, House of
Test Acts
Thane
Toleration Act
Wat Tyler's Rebellion
Witenagemot
Yeoman
York

Other related articles

Bayeux Tapestry
Beatles
Bodleian Library
Boxing Day
British Isles
British Museum
Church of England
Classical music (History)
Cockney
Cricket
Democracy (Democracy in England)
English language
English literature
Europe (pictures)
Fleet Prison
Fox hunting
Furniture
George, Saint
Masque
Newgate Prison
Old Bailey
Painting
Postal services (The creation of the Penny Post)
Rolling Stones
Rugby football
Soccer
Sulgrave Manor
Theater (Theater in other countries)
Tower of London
Victoria and Albert Museum
Westminster Abbey
Weights and measures (Development of units of measure)
Windsor Castle

Outline

I. Government
II. People
- A. Population
- B. Ancestry
- C. Language

III. Way of life
- A. City life
- B. Rural life
- C. Food and drink
- D. Recreation
- E. Education
- F. Religion
- G. The arts

IV. The land
- A. Land regions
- B. Rivers and lakes
- C. Islands

V. Economy
- A. Service industries
- B. Manufacturing
- C. Agriculture and fishing
- D. Mining
- E. Transportation and communication

VI. History

Questions

How has England's location helped make it an important trading center?
What is the *backbone of England*?
What is England's most popular organized sport?
What was the Glorious Revolution?
What are the two houses of Parliament?

How many metropolitan areas does England have?
Who were the Roundheads? Who was their leader?
Where is the point of land called Land's End?
To what church must the British monarch belong?
Why was the reign of Elizabeth I called the Golden Age?

Additional resources

Level I
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Lace, William W. *England.* Lucent Bks., 1997.

Level II
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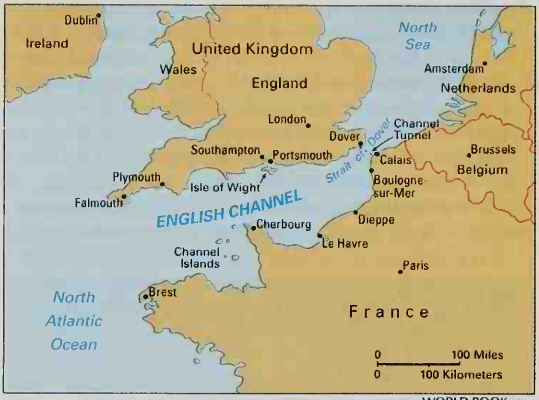

The English Channel separates England and France.

England, Bank of. See Bank of England.

England, Commonwealth of. See England (The Civil War).

English, language. See English language.

English, William Hayden (1822-1896), was the Democratic candidate for vice president of the United States in 1880. He and presidential candidate Winfield S. Hancock were defeated by Republicans James A. Garfield and Chester A. Arthur. English was a member of the United States House of Representatives from Indiana from 1853 to 1861. He also served as a member of the Indiana house of representatives in 1851 and 1852. He was born in Lexington, Indiana. Irving G. Williams

English-Canadian literature. See Canadian literature.

English Channel is a body of water between England and France that connects the Atlantic Ocean and the North Sea. The channel is about 350 miles (563 kilometers) long. It ranges from about 21 to 100 miles (34 to 160 kilometers) in width. The narrowest part of the channel—between the English city of Dover and the French city of Calais—is called the Strait of Dover.

The English Channel is the world's busiest sea passage. About 600 vessels sail through or across the Strait of Dover daily. Ferryboats and hovercraft carry passengers and vehicles across the channel between England and France.

Major ports on the English coast include Dover, Plymouth, Portsmouth, and Southampton. Ports on the channel's French coast include Boulogne-sur-Mer, Calais, Cherbourg, Dieppe, and Le Havre. Popular resorts line the channel coast, including Brighton and Hove, the Isle of Wight, and Bournemouth in England, and Deauville and Le Touquet in France. Islands in the channel include the United Kingdom's Channel Islands, near the French coast; and the United Kingdom's Isle of Wight, near the English coast.

Vessels in the English Channel must often battle rough seas. Currents from the North Sea and the Atlantic Ocean meet in the channel. The currents and strong winds cause the roughness. About 25 dense fogs occur in the channel annually.

Most geologists believe that what are now England and France were joined by a low-lying plain at the end of the Ice Age, about 10,000 years ago. They believe that about 7,000 years ago, large amounts of ice melted nearby. The water from the melting ice raised the level of the sea, flooding the low-lying plain and creating the English Channel.

The channel has long protected England from invasions. The Spanish Armada in the 1500's, Napoleon's fleet in the 1800's, and Adolf Hitler's warships in the 1940's all failed to cross the channel and conquer England.

Since the mid-1700's, there has been interest in building a tunnel beneath the English Channel. Albert Mathieu, a French mining engineer, presented the first plan for a tunnel in 1802. In 1986, the United Kingdom and France announced plans to build a railroad tunnel under the Strait of Dover. Construction on the tunnel began in 1987 and was completed in 1994. Passenger trains and freight trains use the tunnel. Also, the tunnel accommodates special trains that carry automobiles, buses, and trucks through it. See Channel Tunnel.

The English Channel has long been a challenge for swimmers. In 1875, Matthew Webb of the United Kingdom made the first recorded crossing of the channel, swimming from England to France in 21 hours 45 minutes. In 1926, Gertrude Ederle of the United States became the first woman to cross the English Channel, swimming from France to England in 14 hours 39 minutes (see Ederle, Gertrude C.).

Swimmers continue to prove themselves by swimming across the channel. Some swimmers cross the channel two or even three times without stopping. Current records for swimming once across the channel have dropped to about 8 hours or less. D. Ian Scargill

See also Dover, Strait of.

English Civil War. See England (History [The Civil War]).

English cocker spaniel is a popular sporting dog. Outside the United States, it is known as the *cocker spaniel.* The English cocker is alert, well balanced, and strongly built. It is noted for its endurance and intelligence and is a responsible and willing dog, both in the field and as a companion. It differs from other cockers chiefly in size, weighing from 26 to 34 pounds (12 to 15 kilograms) and standing 16 inches (41 centimeters) tall at the shoulder. See also Dog (picture: Sporting dogs).

Critically reviewed by the English Cocker Spaniel Club of America

English foxhound is one of the oldest breeds of hounds. Careful breeding records, dating back to the 1700's, give the ancestry of some purebred English foxhounds through 50 to 60 generations. The breed derives from the staghound, the beagle, and the southern (old English) hound. It has always been used for hunting foxes. The hounds run in packs, trailing the fox by the scent it leaves on the ground. English foxhounds are rarely kept as house pets. They are not affectionate and do not seem to want much petting or attention from

WORLD BOOK photo

The English foxhound is used to hunt foxes.

people. They were first brought to America in 1738.

The English foxhound is sturdy and heavy-boned, with very straight legs. Its height is about 23 inches (58 centimeters), and it weighs from 60 to 75 pounds (27 to 34 kilograms). Its smooth, hard coat is white with patches of black and tan.

Critically reviewed by the American Kennel Club

See also **Fox hunting; Harrier.**

English grammar. See **Grammar.**

English horn is a woodwind instrument. It is actually an alto oboe, not a horn. An English horn consists of a wooden tube 30 inches (76 centimeters) long with a pear-shaped bell at one end. A short metal tube with a double reed is attached to the other end. The player blows on the reed through the short metal tube and plays different notes by pressing keys that open and close holes along the length of the instrument.

Andre P. Larson

See also **Music** (picture: Wind instruments).

English language is the most widely spoken language in the world. It is used as either a primary or secondary language in many countries.

During the 1500's, fewer than 2 million people spoke English. All of them lived in what is now Great Britain. Through the centuries, as the result of various historical events, English spread throughout the world. Today, about 400 million people speak English as their native language. Most of them live in Australia, Canada, Great Britain, Ireland, New Zealand, South Africa, and the United States.

Another 100 million people, chiefly living in Bangladesh, India, Pakistan, and in many African countries, speak English in addition to their own language. An additional 200 million people probably know at least some English.

Characteristics of English

Vocabulary. English has a larger vocabulary than any other language. There are more than 600,000 words in the largest dictionaries of the English language.

Some English words have been passed on from generation to generation as far back as scholars can trace. These words, such as *woman, man, sun, hand, love, go,* and *eat,* express basic ideas and feelings. Later, many words were borrowed from other languages, including Arabic, French, German, Greek, Italian, Latin, Russian, and Spanish. For example, *algebra* is from Arabic, *fashion* from French, *piano* from Italian, and *canyon* from Spanish.

A number of words, such as *doghouse* and *splashdown,* were formed by combining other words. New words are also created by blending words. For example, *motor* and *hotel* were blended into *motel.* Words can be shortened to form new words, as was done with *history* to form *story.* Words called *acronyms* are formed by using the first letter or letters of several words. The word *radar* is an acronym for *ra*dio *d*etection *a*nd *r*anging.

Pronunciation and spelling in English sometimes seem illogical or inconsistent. Many words are spelled similarly though pronounced differently. Examples include *cough, though,* and *through.* Other words, such as *blue, crew, to, too,* and *shoe,* have similar pronunciations but are spelled differently. Many of these variations show changes that occurred during the development of English. The spelling of some words remained the same through the centuries, though their pronunciation changed.

Grammar is the set of principles used to create sentences. These principles define the elements used to assemble sentences and the relationships between the elements. The elements include *parts of speech* and *inflections.*

Parts of speech are the word categories of the English language. Scholars do not all agree on how to describe the parts of speech. The traditional description lists eight classes: nouns, pronouns, verbs, adjectives, adverbs, prepositions, conjunctions, and interjections. The most important relationships of the parts of speech include subject and verb, verb and predicate, and modifier and the word modified.

Some modern scholars also divide the parts of speech into two categories, *content words* and *function words.* Content words are the main parts of speech—nouns, verbs, adverbs, and adjectives—and carry the basic vocabulary meanings. For example, *dog, write, happy,* and *seldom* are content words. These words are also called *form classes.* Function words express relationships between content words in a sentence. For example, *in, because, the, very,* and *not* are function words. They show the grammatical, or structural, meanings of the sentence and are also called *structure classes.* Function words include articles, prepositions, pronouns, and conjunctions. See **Parts of speech.**

English has fewer inflections than most other European languages. An inflection is a variation of the form

of a word that gives the word a different meaning or function. An English noun has only two inflections, the plural and the possessive. Inflections are used to change the tense and number of a verb or the case of a pronoun. Inflections can change adjectives to the comparative or the superlative—for example, *big, bigger, biggest.*

Grammar also defines the order in which parts of speech may be used. The subject of a sentence usually comes first in the word order in English. It is generally followed by the verb and then the object. Single words that modify nouns are usually placed before the noun, but phrases that modify nouns are usually placed after the noun. Words that modify verbs can be put before or after the verb. For more information on word order and sentence patterns, see Sentence.

The development of English

Origins. The earliest source of the English language was a prehistoric language that modern scholars call Proto-Indo-European (PIE). PIE was probably spoken about 5,000 years ago by people who lived in the region north of the Black Sea, in southeastern Europe. These people migrated through the centuries and gradually developed new languages.

One group of people who spoke PIE migrated west and divided into groups who spoke languages that were the ancestors of the Germanic, Greek, and Latin tongues. The Germanic languages developed into English, Danish, Dutch, German, Norwegian, and Swedish. The ancient Greek language became modern Greek, and early Latin grew into French, Italian, and Spanish.

The earliest known language in what is now Britain was spoken by a people called the Celts. The Romans started to conquer the Celts in A.D. 43 and ruled much of Britain until the early 400's, when they returned to Rome. During the mid-400's, Germanic people who lived along the North Sea invaded Britain. The invaders belonged to three main tribes—the Angles, the Jutes, and the Saxons. All three tribes spoke their own Germanic dialect, but they probably understood one another. The Angles settled in central Britain. The word *England* came from a word meaning the *Angle folk* or *land of the Angles,* which was used by the late 800's to refer to all the Anglo-Saxon people and their lands. The language of the Angles, Saxons, and Jutes became known as English.

The history of the English language can be divided into three main periods. The language of the first period, which began about 500 and ended about 1100, is called *Old English.* During the next period, from about 1100 to 1485, the people spoke *Middle English.* The language of the period from about 1485 to the present is known as *Modern English.*

Old English was mainly a mixture of the Germanic languages of the Angles, Jutes, and Saxons. Old English resembles modern German more than it does modern English. Old English had many inflections, as does modern German, and its word order and pronunciation resembled those of modern German.

The vocabulary of Old English was chiefly Germanic, though some words came from the language of the Celts. The Germanic people had learned some Latin words while they lived on the European continent. These people brought some of those words to England and added them to Old English. More Latin words were added during the 500's and the 600's, when Christianity spread in England.

During the late 800's, Viking invaders from Denmark and Norway settled in northeast England. As a result, many words from Scandinavian languages became part of Old English. Gradually, many inflections of Old English were dropped. People also began to put words into a more regular order and to use more prepositions to indicate relationships between words.

Middle English. In 1066, England was conquered by the Normans, a people from the area in France that is now called Normandy. Their leader, William the Conqueror, became king of England. The Normans took control of all English institutions, including the government and the church.

Most of the English people continued to speak English. But many of the members of the upper class in England learned Norman French because they wanted influence and power. The use of French words eventually became fashionable in England. The English borrowed thousands of these words and made them part of their own language. The French-influenced language of England during this period is now called Middle English.

The Normans intermarried with the English and, through the years, became increasingly distant—socially, economically, and culturally—from France. The Normans began to speak English in daily life. By the end of the 1300's, the French influence had declined sharply in England. English was used again in the courts and in business affairs, where French had replaced it.

Modern English. By about 1485, English had lost most of its Old English inflections, and its pronunciation and word order closely resembled those of today. During this period, the vocabulary of English expanded by borrowing words from many other languages. Beginning in the 1600's, the language spread throughout the world as the English explored and colonized Africa, Australia, India, and North America. Different dialects of the English language developed in these areas.

Today, English is the international language of science and technology. In addition, the English language is used throughout the world in business and diplomacy.

Joseph M. Williams

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Additional resources

Burnley, David. *The History of the English Language.* 2nd ed. Addison Wesley Longman, 2000.

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English literature

English literature consists of the poetry, prose, and drama written in the English language by authors in England, Scotland, and Wales. These three lands occupy the island of Great Britain and are political divisions of the United Kingdom of Great Britain and Northern Ireland. They have produced many outstanding writers.

English literature is a rich, varied literature. It includes masterpieces in many forms, particularly the novel, the short story, epic and lyric poetry, the essay, literary criticism, and drama. English literature is also one of the oldest national literatures in the Western world. English authors wrote important works as early as the A.D. 700's.

This article traces the history of English literature from its earliest period to the present. The dates given for each period in the development of the literature are approximate. The article deals with works written in English by authors whose lives and careers have been based in England, Scotland, and Wales. For information on the literature of the United States, Canada, and Ireland, see the articles **American literature**, **Canadian literature**, and **Irish literature**.

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Old English literature (500-1100)

During the A.D. 400's and 500's, three Germanic tribes—the Angles, Jutes, and Saxons—settled in England and established powerful kingdoms. Together, these tribes are called Anglo-Saxons. They used dialects that became known as Old English or Anglo-Saxon. Old English was the chief literary language of England until about 1100. In 597, Saint Augustine of Canterbury began converting the Anglo-Saxons to Christianity. English literature began through the combined influence of the Anglo-Saxon kingdoms and the Christian church.

Old English poetry. Many Old English poems glorified a real or imaginary hero and tried to teach the values of bravery and generosity. Poets used *alliteration* (words that begin with the same sound) and *kennings* (elaborate descriptive phrases). They also used *internal rhyme,* in which a word within a line rhymes with a word at the end of the line.

The first English poet known by name is Caedmon, who lived during the 600's. His only authentic surviving work is a nine-line poem that praises God.

Masters of English literature

The masters of English literature from the 1300's to the present rank among the world's greatest literary figures. The writers in this table appear in chronological order. The table also lists early types of dramas and specific works that played an important part in the development of English literature. Major works written before the 1300's include the epic poem *Beowulf* and adventure stories, called *romances,* about heroes and battles.

Gulliver's Travels (1726) by Jonathan Swift

Romeo and Juliet (about 1596) by William Shakespeare

WORLD BOOK illustrations by Konrad Hack

John Bunyan (1628-1688)
Henry Vaughan (1622-1695)
Andrew Marvell (1621-1678)
John Evelyn (1620-1706)
Abraham Cowley (1618-1667)
Richard Lovelace (1618-1658)
Jeremy Taylor (1613-1667)
King James Bible (1611)
Sir John Suckling (1609-1642)
John Milton (1608-1674)
Sir Thomas Browne (1605-1682)
Izaak Walton (1593-1683)
George Herbert (1593-1633)
Robert Herrick (1591-1674)
Francis Beaumont (1584?-1616)
John Webster (1580?-1625?)
Robert Burton (1577-1640)
Ben Jonson (1572-1637)
John Donne (1572-1631)
Thomas Campion (1567-1620)
Thomas Nash (1567-1601)
William Shakespeare (1564-1616)
Christopher Marlowe (1564-1593)
George Peele (1558?-1597?)
Thomas Kyd (1558-1594)
Robert Greene (1558-1592)
John Lyly (1554?-1606)
Sir Philip Sidney (1554-1586)
Edmund Spenser (1552?-1599)
Earl of Surrey (1517?-1547)
Sir Thomas Wyatt (1503?-1542)

Geoffrey Chaucer (1340?-1400)
John Gower (1330?-1408)
Miracle plays (1300's)
Mystery plays (1300's)
Le Morte Darthur (about 1469)
Morality plays (1400's)

1300 1400 1500 1600

The first major work of English literature is the epic *Beowulf.* Epics are long narrative poems that focus on heroic and extraordinary actions. Many are based on legend or myth, and their language is dignified and serious. One or more unknown authors wrote *Beowulf* some time between 750 and 1100. The poem tells about the adventures of a warrior named Beowulf.

After about 750, poetry flourished in Northumbria, an Anglo-Saxon kingdom in the north. There, poets wrote verses about the lives and hardships of saints. The leading Northumbrian poet was Cynewulf.

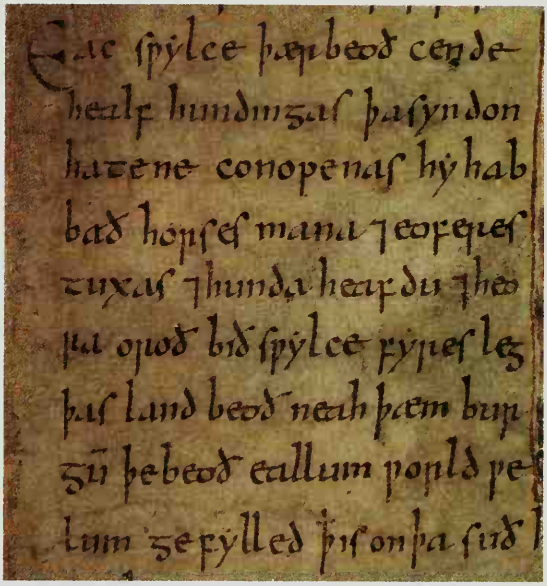
Old English prose. Most prose writers wrote in Latin until the late 800's, when Alfred the Great became king of Wessex in southwestern England. Alfred translated or ordered the translation of several works from Latin into Old English. One of the most important of these works was the *Ecclesiastical History of the English People* (731) by a monk called Saint Bede or the Venerable Bede. This is the first history of the English people and a valuable source of information about English life from the late 500's to 731. A monk named Aelfric wrote *homilies* (short moral essays) in Old English during the 990's. From about 892 to 1154, a number of authors contributed to the *Anglo-Saxon Chronicle,* which was a record of current events in England.

Middle English literature (1100-1485)

In 1066, Norman invaders from France conquered England. For more than 200 years thereafter, members of the royal court and the upper class spoke French. Only the common people continued to speak English. By about 1300, however, English had again become the chief national language, but in an altered form now called Middle English.

The development of English romances. Medieval romances originated in France during the 1100's. By the end of the 1200's, they had become the most popular literary form in England. Like epics, romances described the adventures of heroes, but their plots depended more on supernatural events and featured stories of love and high-born ladies. Romances were written in prose as well as verse.

In 1155, a Norman poet named Wace completed the first work that mentioned the Knights of the Round Table, who were led by the legendary British ruler King Arthur. King Arthur and his knights became a favorite subject in English romances. During the 1400's, Sir Thomas Malory wrote a prose work called *Le Morte Darthur (The Death of Arthur).* Malory's romance is the most complete English version of stories about Arthur.



The British Library, London

Beowulf was the first major work in English literature. The poem was written in Old English, the earliest form of English. This detail is from a manuscript produced about 1000.

The age of Chaucer. The greatest writer of the Middle English period was the poet Geoffrey Chaucer. His masterpiece is *The Canterbury Tales* (late 1300's), an unfinished collection of comic and moral stories. Chaucer introduced a rhythmic pattern called *iambic pentameter* into English poetry. This pattern, or meter, consists of 10 syllables alternately unaccented and accented in each line. The lines may or may not rhyme. Iambic pentameter became a widely used meter in English poetry.

Chaucer's friend John Gower wrote verse in Latin and English. His *Confessio Amantis* (about 1390) is a Middle English poem that uses Biblical, medieval, and mythological stories to discuss the problems of romantic love. A religious and symbolic poem called *Piers Plowman* has been attributed to William Langland, though several others may have contributed to it. It describes a series of dream visions that show humanity's struggle to arrive at spiritual salvation. Three versions of the poem appeared in the late 1300's. Like the works of Chaucer and Gower, *Piers Plowman* provides a fascinating glimpse of English life during the 1300's.

Another important work of the late 1300's is a poem called *Pearl.* In this poem, a father mourns the death of his young daughter. He is finally comforted through a dream vision in which the girl tells him of the blessings of heaven. *Pearl* is unusual because it combines the alliterative style of earlier English verse with a strict rhythmic structure and complex rhyme scheme.

Early English drama developed from scenes that monks acted out in churches to illustrate Bible stories. The scenes grew into full-length works called *mystery plays* and *miracle plays.* Mystery plays dealt with events in the Bible, and miracle plays with the lives of saints.

During the 1400's, *morality plays* first appeared in English drama. Morality plays featured characters who represented a certain quality, such as good or evil. These dramas were less realistic than the earlier plays and were intended to teach a moral lesson.

Middle English prose consists mainly of religious writings. Often such works were intended for women readers, because women were much less likely than men to be taught Latin. One well-known work of the period is *The Book of Margery Kempe,* dictated during the 1430's by a woman who could not read or write. It is an autobiography that describes Kempe's mystical visions, her pilgrimages, and her struggles with the official church of her time.

The beginning of Modern English (1485-1603)

During the late 1400's, Middle English began to develop into Modern English. By the late 1500's, people in England were speaking and writing English in a form much like that used today.

Queen Elizabeth I reigned from 1558 to 1603. During this period, usually called the Elizabethan Age, English writers produced some of the greatest poetry and drama in world literature.

A number of developments contributed to the brilliant literary output of the Elizabethan Age. One of the most important occurred in 1476, when William Caxton set up the first printing press in England. Before that time, books and all other literary works had to be slowly and laboriously copied by hand. Printing made it possible to produce far more books and at far lower cost. The greater availability of books and their lower cost stimulated a desire among many people to learn how to read. As literacy increased, so did the demand for books.

Religious debates also played a role in the development of a reading public. During the reign of Elizabeth's father, King Henry VIII, the English church became independent of the Roman Catholic Church. Under the influence of the Protestant Reformation, Bible reading was encouraged. During the 1520's, William Tyndale made an important new English translation of the Bible.

During the 1500's, English scholars joined other European scholars in rediscovering the cultures of ancient Greece and Rome, which they had largely neglected for hundreds of years. Translations of Greek and particularly Roman literary works strongly influenced Elizabethan writers. In addition, new literary forms were introduced into English literature. For example, English authors adopted directly or modified such literary forms as the essay from France and the sonnet from Italy.

During the Elizabethan Age, the English also explored and colonized distant lands. Wealth from the colonies poured into England. A newly rich merchant class made London a great commercial center. The merchants and the nobility wanted entertainment and fine art and were willing to pay for them. Writers, painters, and musicians flocked to London, making it a European cultural center.

Elizabethan poetry. Three chief forms of poetry flourished during the Elizabethan Age. They were (1) the lyric, (2) the sonnet, and (3) narrative poetry.

The lyric. A lyric is a short poem that expresses private emotions and moods in a songlike style. Thomas Campion wrote many beautiful lyrics in his *Books of Airs* (1601 to about 1617).

The sonnet is a 14-line poem with a certain pattern of rhyme and rhythm. Elizabethan poets wrote two types of sonnets, Italian and English. The two types differed in

the arrangement of the rhymes. Sir Thomas Wyatt introduced the sonnet from Italy into English literature in the early 1500's. The Earl of Surrey modified the form into the English sonnet. Their verses were published in a collection commonly called *Tottel's Miscellany* (1557).

Edmund Spenser and William Shakespeare wrote *sonnet sequences,* groups of sonnets based on a single theme. Spenser and Sir Philip Sidney wrote sequences of love sonnets. Shakespeare wrote a sequence addressed to a nobleman who was his patron and to an unknown "dark lady."

Narrative poetry. A narrative poem tells a story. In addition to sonnets, Shakespeare and Spenser wrote narrative poems. Shakespeare based his *Venus and Adonis* (1593) on a Roman myth and *The Rape of Lucrece* (1594) on an event from Roman history.

Perhaps the most ambitious Elizabethan narrative poem is *The Faerie Queene* by Spenser. The poet borrowed heavily from medieval romances to invent an imaginary land representing British and Christian ideals. The style of the poem is *allegorical.* In allegorical writing, people and objects are used to represent abstract ideas, such as holiness and justice. *The Faerie Queene* combines those abstract moral meanings with striking visual imagery.

Elizabethan drama. In 1576, James Burbage built England's first playhouse, called The Theatre, in a suburb of London. Until this time, drama had been performed in the streets, in homes and palaces, and at universities. After Burbage's theater, other playhouses opened and the popularity of drama rapidly increased.

Elizabethan drama was noted for its passion and vitality. Thomas Kyd's play *The Spanish Tragedy* (1580's) was one of the earliest Elizabethan dramas. It is filled with scenes of violence and madness and set a pattern for themes of murder and revenge in later plays.

A group of leading Elizabethan playwrights were known as the "University Wits" because they had attended the famous English universities at Oxford or Cambridge. These playwrights included Robert Greene, Christopher Marlowe, and George Peele. Marlowe was the most important dramatist among the Wits. He wrote tragedies that center on strong personalities. These works include *Tamburlaine the Great* (about 1587) and *The Tragical History of Doctor Faustus* (about 1588).

The greatest Elizabethan playwright was William Shakespeare. No other English author has equaled his brilliant verse and characterizations. For detailed information about his writings, see **Shakespeare, William.**

Elizabethan fiction. The Elizabethan Age produced some of the first works of prose fiction in English. Readers especially liked fanciful, elaborately told stories of love and adventure. John Lyly popularized an artificial, elegant style in *Euphues: The Anatomy of Wit* (1578). Sir Philip Sidney wrote in Lyly's style in *Arcadia* (1580). Both works are *pastorals* (stories that idealize the lives of shepherds). Thomas Nashe wrote in a more realistic style. In *The Unfortunate Traveller* (1594), he described the adventures of one of King Henry VIII's pages.

The early and middle 1600's

King James I, who ruled from 1603 to 1625, and his son Charles I, who took the throne in 1625, quarreled often with Parliament. Civil war broke out in 1642 between the king's followers, called Cavaliers, and Parliament's chief supporters, a religious and political group called the Puritans. In 1648, the Puritans won the war. They beheaded Charles in 1649 and ruled England until 1660.

Metaphysical and Cavalier poets were two major groups of poets during the 1600's. The Metaphysical poets included John Donne, their leader; Abraham Cowley; Richard Crashaw; George Herbert; Andrew Marvell; and Henry Vaughan. The Cavalier poets, who were associated with the court of Charles I, included Thomas Carew, Robert Herrick, Richard Lovelace, and Sir John Suckling.

The Metaphysical poets used comparatively simple language, but they often created elaborate images called *conceits.* Donne wrote passionate love poetry until he converted from Roman Catholicism to the Anglican faith. He became an Anglican priest in 1615. After his conversion, Donne wrote equally passionate religious poetry. Several other Metaphysical poets also wrote religious verse. In contrast to the serious Metaphysical poets, the Cavalier poets were best known for their dashing love poetry.

Jacobean drama is the name given to the plays written during the reign of James I. Jacobean tragedies reflected Elizabethan drama, especially in such characteristics as violent action, spectacle, and the revenge theme. John Webster's drama *The Duchess of Malfi* (about 1613) is a masterpiece of revenge tragedy. *Satiric comedies,* which poked fun at various subjects, were also popular. In *The Knight of the Burning Pestle* (1607?), for example, Francis Beaumont ridiculed earlier dramas and romances about elegant heroes and also satirized the newly rich merchant class.

Ben Jonson wrote plays that showed the influence of ancient Roman drama. His comedies *Volpone* (1606) and *The Alchemist* (1610) satirize universal human failings such as greed, ignorance, or superstition.

In 1642, the Puritans ordered the closing of the theaters, claiming that plays were wicked. The order remained in effect for 18 years.

Prose writings. In 1604, King James I authorized a group of scholars to prepare a new English version of the Bible. It appeared in 1611 and became known as the King James Version or Authorized Version. Although it borrowed from earlier translations, such as Tyndale's, the King James Version was a landmark in the development of English prose. Its eloquent yet natural style had enormous influence on English-speaking writers.

Lady Mary Wroth, Sir Philip Sidney's niece, continued the tradition of writing in her uncle's elegant, artificial style. She combined prose and poetry in *Urania* (1621). Robert Burton's *The Anatomy of Melancholy* (1621) was written as a psychological study of the causes, symptoms, and cures of melancholy, which Burton believed all people experienced. But at the same time Burton explored a wide range of human learning and effort.

Many authors wrote philosophical works during the early and middle 1600's. Donne composed a series of meditations on sickness, sin, and death in *Devotions upon Emergent Occasions* (1624). Sir Thomas Browne, a physician, and Jeremy Taylor, an Anglican bishop, wrote works noted for their beautiful prose style. In *Religio Medici* (1642), Browne gave his learned opinions on a variety of subjects, including miracles and witchcraft. Taylor is best known for two religious essays, *Holy Liv-*

ing (1650) and *Holy Dying* (1651). In contrast to these serious works, Izaak Walton wrote *The Compleat Angler* (1653 a light-hearted but thoughtful book on fishing.

John Milton was the greatest English writer of the mid-1600's. Milton was deeply involved in the political and religious debates of his time and supported the Puritans during the English Civil War. He wrote prose and verse on many subjects before, during, and after the war. These writings include an attack on censorship, *Areopagitica* (1644). In this piece, Milton argued that knowledge and virtue can only grow when different opinions have a chance to be openly debated.

Milton's greatest achievement is *Paradise Lost* (1667), an epic based on the story of Adam and Eve. Its vivid descriptions of heaven, hell, and the Garden of Eden, and its rich and musical blank verse, make it one of the most admired and imitated works in English literature.

Restoration literature (1660-1700)

Puritan rule ended in 1660, when Parliament restored the monarchy under Charles II. The period from 1660 to 1700 is known as the Restoration.

The Puritans had attempted to enforce a strict moral code during their years in power. The Restoration brought a strong reaction against this code. The nobility and upper class, in particular, became known for carefree and often morally loose living. Restoration writers reflected this relaxed morality in their works.

John Dryden followed Milton as the outstanding literary figure of the Restoration. Dryden wrote poetry, popular dramas, and literary criticism. During his career, he shifted his support from the Puritans to the restored monarchy. Late in life, he converted from the Anglican faith to Roman Catholicism. Many of Dryden's poems reflect these political and religious shifts. His political satire *Absalom and Achitophel* (1681) attacks the enemies of the future James II. In *The Hind and the Panther* (1687), Dryden justified his conversion to Catholicism.

Dryden's best plays include *Marriage à la Mode* (1672), a comedy, and *All for Love* (1677), a tragedy. Dryden also wrote some of the finest literary criticism in English.

Restoration drama. After Charles II became king in 1660, the theaters reopened and an important period in English drama began. Two types of plays rapidly dominated Restoration stages: (1) the comedy of manners and (2) the heroic tragedy.

The comedy of manners was witty, sometimes cynical, and occasionally indecent. It treated love and romantic intrigue in a light, often broadly humorous way. The best comedies of manners included *The Country Wife* (1675) by William Wycherley and *The Way of the World* (1700) by William Congreve.

The heroic tragedy had a complicated plot that dealt with the conflict between love and honor. Most of these plays were set in far from England. Little action took place on the stage, and the characters spoke in elegant, noble-sounding *heroic couplets.* A heroic couplet is a verse form consisting of two rhymed lines of 10 syllables each. Dryden wrote several heroic tragedies, including *The Conquest of Granada* (1670, 1671).

Restoration prose. During the Restoration, prose became less elaborate than had been fashionable earlier in the 1600's. Writers tried to express themselves in a style that was clear, simple, and direct.

Aphra Behn's *Oroonoko* (first published about 1678)) tells the story of an African prince sold into slavery who leads a tragic rebellion against his English captors. In the novel's descriptive passages, Behn drew on her experiences in the English colony of Surinam. Her interest in factual, realistic background was new to English fiction.

John Bunyan wrote the popular Christian allegory *The Pilgrim's Progress* (1678, 1684). The work shows the journey of its hero, Christian, through this world to the heavenly city of salvation in the world beyond. The diaries of Samuel Pepys and John Evelyn are also vividly written. They provide a delightful and detailed view of English life in the late 1600's.

The Augustan Age (1700-1750)

The period in English literature from 1700 to about 1750 is called the Augustan Age, named for the Roman emperor Augustus, who reigned from 27 B.C. to A.D. 14. English authors tried to imitate or recapture many of the philosophic and literary ideals of Augustan Rome. In particular, they admired the ideals of reason and common sense, and they tried to achieve balance and harmony in their writings. The Augustan Age of English literature is also known as the Neoclassical period.

Swift and Pope. Satire was one of the most common types of literature during the Augustan Age. In spite of the Augustan emphasis on reason, many of the satires were extremely bitter and personal. The leading satirists of the period were Jonathan Swift in prose and Alexander Pope in poetry.

Swift attacked hypocrisy in *Gulliver's Travels* (1726), the most famous satire in English. In *A Modest Proposal* (1729), Swift, who was born and lived much of his life in Ireland, satirized the harshness and indifference that he saw in England's rule of Ireland.

Pope perfected the heroic couplet, giving its two rhymed lines a quality of balance and wit that often echoed his themes. In *The Rape of the Lock* (1712-1714), he ridiculed fashionable society. In *An Essay on Man* (1733-1734), he advised readers to take the middle way—avoid extremes—in all things. He wrote with especially cutting brilliance about the authors of his time and their weaknesses in *The Dunciad* (1728-1743). One of Pope's most important nonsatirical poems is *Windsor Forest* (1713). It uses England's Windsor forest as a symbol of social harmony, weaving patriotic reflections on history, politics, and morality into a description of the landscape.

Addison and Steele. Joseph Addison and Sir Richard Steele were the outstanding essayists of the Augustan Age. They published many of their essays in two periodicals, *The Tatler* (1709-1711) and *The Spectator* (1711-1712). Both writers described and criticized the social customs and attitudes of their day. Their essays helped form middle-class tastes in manners, morals, and literature. In addition, Addison's pure and elegant prose style served as a model throughout the 1700's.

The rise of the novel. The development of the novel is one of the great achievements of English literature. With the novel, English prose fiction became more realistic and addressed a wider, middle-class audience. One of the major figures in the development was Daniel Defoe. He wrote realistic stories consisting of loosely connected incidents that were presented as actual happen-

ings. Defoe's *Robinson Crusoe* (1719) and *Moll Flanders* (1722) are early examples of the novel, but they lack the unified plot that became typical of that literary form.

Many scholars consider Samuel Richardson the first true novelist in English. He wrote *epistolary novels,* which take the form of letters exchanged between the novel's characters. Richardson's novels are highly moralistic. His first novel, *Pamela* (1740), tells about a servant girl whose virtuous refusal to be seduced by her master eventually leads him to marry her. Richardson's masterpiece is *Clarissa* (1748), a tragic story of a young woman tricked into leaving her home and raped by a villainous nobleman. It is remarkable for the detailed exploration of the characters' states of mind.

The novels of Henry Fielding and Tobias Smollett emphasize vigorous humor and satire. Fielding ridiculed *Pamela* in *An Apology for the Life of Mrs. Shamela Andrews* (1741). Fielding was a master at putting together a complex plot. His *Tom Jones* (1749) is perhaps the greatest comic novel in English. Smollett's *The Expedition of Humphry Clinker* (1771) gives a humorous account of a family's travels through England and Scotland.

Laurence Sterne was another leading novelist. His *The Life and Opinions of Tristram Shandy, Gentleman* (1760-1767) has almost no story. The narrator, Tristram, tries to write his life story but keeps breaking off to discuss other topics. The work inspired many experimental novelists of the 1900's.

The Age of Johnson (1750-1784)

Samuel Johnson dominated English literature from about 1750 until his death in 1784. He was as famous for his conversation—in which he sometimes voiced outrageous opinions—as he was for his writings.

Johnson's literary achievements are remarkable. His *Dictionary of the English Language* (1755) is noted for its scholarly definitions of words and the use of excellent quotations to illustrate the definitions. In *The Lives of the English Poets* (1779-1781), Johnson critically examined the work of 52 poets and did much to establish literary criticism as a form of literature. Johnson also wrote articles, reviews, essays, and poems. His prose work *Rasselas* (1759) is a philosophical attack on people who seek an easy path to happiness.

The Johnson circle. Johnson's friends were the most important writers of the late 1700's. They included Oliver Goldsmith; Richard Brinsley Sheridan; Edmund Burke; and Johnson's biographer, James Boswell.

Goldsmith's novel *The Vicar of Wakefield* (1766) tells about the misfortunes of a kindly clergyman and his family. *The Deserted Village* (1770) is a poem that movingly describes the decline of an English village. Goldsmith's great play is the classic comedy *She Stoops to Conquer* (1773). Sheridan wrote two clever comedies of manners, *The Rivals* (1775) and *The School for Scandal* (1777). Burke composed essays on government, history, and beauty. His *Philosophical Enquiry into the Origin of Our Ideas of the Sublime and Beautiful* (1757) anticipates many ideas of Romantic writers of the 1800's. His attack on the French Revolution, *Reflections on the Revolution in France* (1790), quickly became one of the most influential books on politics ever written.

Fanny Burney became part of Johnson's circle through her father, the music historian Dr. Charles Burney. In

Detail of an engraving by R. B. Parkes from a lost oil painting (1860) by Eyre Crowe; Radio Times Hulton Picture Library

Samuel Johnson, *right,* was the most influential English author and critic of the late 1700's. Johnson often exchanged opinions on literature in London's Mitre Tavern with such writers as Oliver Goldsmith, *left,* and James Boswell, *center.*

such novels as *Evelina* (1778) and *Cecilia* (1782), she combined Richardson's moral concerns and psychological insight with Fielding's satirical, humorous tone. Boswell brilliantly recorded Johnson's eccentricities and witty conversations in *The Life of Samuel Johnson* (1791), one of the great biographies in literature.

Ignatius Sancho was the first African prose writer published in England. Sancho was born on a slave ship on its way to America. When he was 2 years old, he was taken to England. Sancho was especially admired as a letter writer. His *Letters* (1782) were published two years after his death. During the late 1700's and early 1800's, several former slaves wrote memoirs of their experiences, notably Olaudah Equiano's *The Interesting Narrative of the Life of Olaudah Equiano* (1789). Equiano offers a vivid account of his childhood, enslavement, and eventual freedom.

Romantic literature (1784-1832)

English writers of the late 1700's and early 1800's believed that the Augustan ideals of harmony and moderation were narrow and artificial. These writers are called Romantics. The Romantics emphasized the creative power of the human imagination and placed increasing value on private experience and the natural world.

In 1789, the French Revolution began, and from 1792 through 1815, England was often at war with France. Romantic writers responded to these events with a complex mixture of sympathy for the democratic ideals of the revolution and patriotic support for the English war effort. England's colonial interests overseas also grew at this time, and many of the most popular Romantic works were set in distant lands associated with those interests.

The Preromantics is the name given to a group of poets of the mid-1700's whose work first touched on important Romantic themes and ideas. Their writing reflected the awareness of social problems, the love of nature, and the fascination with myth and mystery that

became typical of Romanticism.

The Scottish poet Robert Burns wrote about rural characters. He often used Scots dialect. Burns's most popular verses include "Auld Lang Syne" (about 1788) and "Comin Thro' the Rye" (about 1796).

The leading Preromantic poet was William Blake. Blake was an important printer and engraver as well as a poet. His work expresses an intensely personal vision and, partly for this reason, was barely known when he was alive. Many of his most direct lyrics are collected in *Songs of Innocence* (1789) and *Songs of Experience* (1794). His poetry combines anger at the social injustices of his time with richly imagined portraits of a freer, more just society.

Romantic poetry. William Wordsworth and Samuel Taylor Coleridge were the first important English Romantic poets. They produced a joint volume of poems titled *Lyrical Ballads* (1798). Wordsworth's preface to the second edition (1800) is an important statement of Romantic ideas about the continuing value of poetry. He explained that his poetry used everyday language rather than the elevated poetic language of such earlier writers as Dryden and Pope because everyday language comes closer to expressing genuine human feeling. For the same reason, he wanted to write about everyday topics, especially rural, unsophisticated subjects.

Wordsworth and Coleridge lived most of their lives in the scenic Lake District of northwestern England and wrote expressively about the beauties of nature and the thoughts that natural beauty inspires. Many of their blank verse poems are written in a meditative, conversational tone new to English poetry.

Wordsworth's poems also emphasize the mind of the poet. His memories of his childhood and his experiences in France during its revolutionary period are the subject of his great autobiographical poem, *The Prelude*, published in 1850, shortly after his death.

Coleridge's most famous poems are "The Rime of the Ancient Mariner" (1798) and "Christabel" (written in 1799 and 1800 but not published until 1816). Both deal with supernatural subjects. Coleridge was also an important literary critic and philosopher. In *Biographia Literaria* (1817), he argued that the imagination is the active power in the creation of human experience.

The next generation of romantic poets included Lord Byron, Percy Bysshe Shelley, and John Keats. They criticized Wordsworth and Coleridge for giving up on the ideals of the French Revolution. These poets were interested in reviving classical subject matter in the manner of Renaissance poets. Byron and Shelley especially admired the ideal of ancient Greek democracy, and Byron died participating in the fight for Greek independence.

Byron wrote a series of "Eastern" tales set mainly in Turkey and Greece. He created a partly autobiographical hero in such lengthy works as *Childe Harold's Pilgrimage* (1812-1818) and the unfinished *Don Juan* (1819-1824). While much of Byron's poetry is dark and self-dramatizing, *Don Juan* is written in a comic style. The poem makes fun of many aspects of society, including Byron's own popular as a celebrity author.

Shelley wrote poetry that was both politically involved and intensely lyrical. Many of his poems call for political and social reforms in language that is melodious and complex. In his long drama *Prometheus Unbound* (1820), Shelley argued that reform needs to be based on inner transformation. For the world to change, people's beliefs must change.

John Keats wrote intense, vivid poems that capture the experience of beauty and its inevitable passing. He wrote some of his most important poems in response to other works of art. His major works include "Ode on a Grecian Urn" (1819) and "Ode to a Nightingale" (1819).

Romantic prose included essays, criticism, journals, and novels. During the 1790's, many important prose works were written in response to the French Revolution. They included Mary Wollstonecraft's *A Vindication of the Rights of Men* (1790), which supported the revolution against Edmund Burke's attacks. Wollstonecraft also wrote one of the first feminist works, *A Vindication of the Rights of Woman* (1792). In it, she argued for a woman's right to education and independence.

The leading Romantic essayists were Thomas De Quincey, William Hazlitt, and Charles Lamb. De Quincey's *Confessions of an English Opium Eater* (1821) is typical of the personal, revealing essay that was popular during the early 1800's. Hazlitt wrote outstanding critical studies of English literature. His writings helped revive interest in the plays of the Elizabethan Age. He also wrote political and personal essays in a sparkling, forceful prose that seems to speak directly to his readers. Lamb's warm, humorous essays were collected in *Essays of Elia* (1823) and *Last Essays of Elia* (1833).

Horror stories called *Gothic novels* became popular during the late 1700's and early 1800's. Most of these tales deal with supernatural or seemingly supernatural events Horace Walpole wrote the first Gothic novel, *The Castle of Otranto* (1764). Another Gothic novelist, Ann Radcliffe, used detailed landscape descriptions to show her characters' mood and attitude. Mary Wollstonecraft Shelley, the daughter of Mary Wollstonecraft and the wife of Percy Bysshe Shelley, wrote *Frankenstein* (1818), one of the most daring and popular Gothic novels.

The two greatest novelists of the Romantic period were Jane Austen and Sir Walter Scott. Austen wrote about middle-class life in small towns and in the famous resort city of Bath. Her writing is elegant and playful, but below the surface it has a surprising bite. The heroines in such Austen novels as *Pride and Prejudice* (1813) and *Emma* (1816) are known for their independence and wit.

Scott wrote many novels that take place in the Scottish Highlands or Edinburgh. He also used historical settings to comment on important issues of his time. These are the first truly historical novels in English literature.

Victorian literature (1832-1901)

Victoria became queen of the United Kingdom in 1837. Her reign, the longest in English history, lasted until 1901. This period is called the Victorian Age.

During the Victorian Age, the British Empire reached its height and covered about a fourth of the world's land. Industry and trade expanded rapidly, and railroads and canals crisscrossed the country. Science and technology made great advances. The middle class grew enormously. In spite of this prosperity, factory laborers and farmworkers lived in terrible poverty.

The Victorian Age's new scientific theories seemed to challenge many religious beliefs. The most controversial theory appeared in *The Origin of Species* (1859) by the

biologist Charles Darwin. In the book, he stated that every species of life develops from an earlier one, which seemed to contradict the Biblical account of the creation of life. The theories of Darwin and other scientists led many people to feel that traditional values could no longer guide their lives.

Victorian writers dealt with the contrast between the prosperity of the middle and upper classes and the wretched condition of the poor. In the late 1800's, they also analyzed the loss of faith in traditional values.

Early Victorian literature includes some of the greatest and most popular novels ever written. Most novelists of the period wrote long works with numerous characters. In many instances, the authors included actual events of the day in their tales.

The novels of Charles Dickens are noted for their colorful—and sometimes eccentric—characters. In *Oliver Twist* (1837-1839) and *David Copperfield* (1849-1850), Dickens described the lives of children made miserable by cruel or thoughtless adults. Many of his later novels picture the grim side of Victorian life. In *Bleak House* (1852-1853), Dickens criticized the courts, the clergy, and the upper class neglect of the poor. His novels often balance their harsh social criticism with satirical humor, idealized heroines, and sentimental scenes of family life.

William Makepeace Thackeray created a masterpiece of Victorian fiction in *Vanity Fair* (1847-1848). The story follows the lives of many characters at different levels of English society during the early 1800's.

The novels of the three Brontë sisters—Emily, Charlotte, and Anne—have many Gothic and Romantic elements. The novels are known especially for their psychologically tormented heroes and heroines. Emily's

Engraving (1838) by George Cruikshank; The Newberry Library, Chicago

Oliver Twist is one of Charles Dickens's novels that attacked social injustice during the Victorian Age. In this scene, the orphan Oliver begs the cruel head of his orphanage for more food.

Wuthering Heights (1847) and Charlotte's *Jane Eyre* (1847) are among the best-loved works of Victorian fiction.

Elizabeth Gaskell wrote about confrontations between factory workers and owners in *Mary Barton* (1848) and *North and South* (1854-1855). She also wrote an important biography of author Charlotte Brontë (1857).

Several writers wrote nonfiction that dealt with what they believed to be the ills of the time. For example, Thomas Carlyle attacked greed and hypocrisy in *Sartor Resartus* (1833-1834). John Stuart Mill discussed the relationship between society and the individual in his long essay *On Liberty* (1859). In a later essay, *The Subjection of Women* (1869), he argued that women should have the same political rights as men.

Later Victorian literature. During the late 1800's, an uneasy tone appeared in much of the best Victorian poetry and prose. Matthew Arnold described his doubts about modern life in such poems as "The Scholar-Gypsy" (1853) and "Dover Beach" (1867). His most important literary achievements are his critical essays on culture, literature, religion, and society. Many of them were collected in *Culture and Anarchy* (1869).

John Ruskin and Walter Pater were other important critics. Ruskin was a major critic of painting and architecture. In *Unto This Last* (1862), Ruskin argued that the modern industrial economy was ruining England. He believed that the Middle Ages offered more humane and spiritually satisfying ideals because they allowed for individual development and craftsmanship. Pater's *Studies in the History of the Renaissance* (1873 is a collection of his essays about Renaissance writers and painters.

Alfred, Lord Tennyson and Robert Browning were the two most important late Victorian poets. In *In Memoriam* (published in 1850), Tennyson tried to reconcile traditional Christian faith with modern science. Idylls of the King (1842-1885) returned to medieval legends of King Arthur and his knights.

Browning created finely drawn character studies in poems called *dramatic monologues.* In these poems, a real or imaginary character narrates the story. Browning's best-known work is *The Ring and the Book* (1868-1869). He based the poem on an Italian murder case of 1698. Twelve characters discuss the case, each from his or her own point of view. Elizabeth Barrett Browning, Browning's wife, wrote a famous sequence of love poems called *Sonnets from the Portuguese* (1850). In her long "novel in verse" *Aurora Leigh* (1857), she commented on the social role of women and poetry in the 1800's.

The Pre-Raphaelites were a group of poets and painters who followed Ruskin and took their inspiration from the Middle Ages. The most important Pre-Raphaelite poet, Dante Gabriel Rossetti, was also an important painter. His partly autobiographical sonnet sequence *The House of Life* (1881) draws connections between experiences of love, death, and art.

Gerard Manley Hopkins wrote experimental religious verse. His poems were not published until 1918, almost 30 years after his death. Hopkins filled his poetry with rich word pictures and unusual word combinations. The "Terrible" sonnets (written in 1885) express experiences of extreme spiritual loneliness and suffering.

The leading late Victorian novelists were George Eliot (the pen name of Mary Ann Evans), Wilkie Collins, George Meredith, Anthony Trollope, and Thomas Har-

dy. Eliot's novels address social and moral problems. Her masterpiece is *Middlemarch* (1871-1872). Collins wrote stories of crime and suspense. His book *The Moonstone* (1868) is one of the first mystery novels.

Meredith's novels are noted for their witty style and sophisticated psychological treatment of character. His works include the novels *The Ordeal of Richard Feverel* (1859) and *The Egoist* (1879). The six "Barsetshire Novels" of Trollope are satires of life in rural England. They often tell of conflicts within the Church of England, usually in a humorous way. Hardy wrote about characters defeated by an apparently hostile fate. He used the landscape of the imaginary county of Wessex to help create the brooding atmosphere of such novels as *The Mayor of Casterbridge* (1886) and *Jude the Obscure* (1895).

From the late 1700's to the late 1800's, almost no important dramas were produced in England. But by 1900, a number of playwrights had revived the English theater both with witty comedies and with realistic dramas about social problems of the time.

Oscar Wilde recalled the glittering Restoration comedy of manners in *The Importance of Being Earnest* (1895). George Bernard Shaw wrote plays exposing the faults he saw in society. Shaw, like Wilde an Irishman who settled in England, addressed England's relation to Ireland in the play *John Bull's Other Island* (1904).

Literature before and after the world wars

Literature before World War I. Several outstanding authors gained fame during the period that began with Queen Victoria's death in 1901 and ended with the outbreak of World War I in 1914. A number of these authors wrote novels and plays of social criticism. Late in the period, a group of poets returned to the values of the Romantics, writing verse in the style of Wordsworth.

After Victoria died, her oldest son became King Edward VII. The term Edwardian is often applied to the period of Edward's reign—1901 to 1910. The leading Edwardian novelists included Arnold Bennett and H. G. Wells. In *The Old Wives' Tale* (1908) and other realistic novels, Bennett wrote about the dull, narrow lives of the middle class in the small towns of central England. Wells became famous for *The War of the Worlds* (1898) and other science fiction novels. However, he also wrote political and satirical fiction. Shaw continued to attack uncritically accepted social values in such plays as *Major Barbara* (1905) and *The Doctor's Dilemma* (1906).

Joseph Conrad wrote probing novels on such themes as guilt, heroism, and honor. Many of his novels depict life at sea and show insight into the physical and psychological impact of imperialism.

Beginning about 1905, a group of writers and artists met frequently in a section of London called Bloomsbury to discuss intellectual questions. They were known as the Bloomsbury Group. The leading Bloomsbury writer was Virginia Woolf. In such novels as *Mrs. Dalloway* (1925) and *To the Lighthouse* (1927), she wrote with great insight about the collapse of belief systems of the 1800's and its transforming effect on the lives of her characters. Woolf used a technique called *stream of consciousness* to reveal the inner thoughts of her characters, capturing even their most fleeting experiences. Woolf also wrote critical essays on literature and society. In *A Room of One's Own* (1929), she discussed many of the social, economic, and psychological disadvantages facing women writers.

The leading poets of the early 1900's belonged to a group called the Georgians. The group's name came from George V, who became king on the death of his father, Edward VII. The Georgians wrote poetry about nature and the pleasures of rural living. Their work was idealistic and traditional. The most important members of the group included Rupert Brooke and John Masefield. Brooke was one of several promising young writers who died during World War I.

Poetry between the wars. English poetry changed in both form and subject matter between the end of World War I in 1918 and the outbreak of World War II in 1939. The horrifying battlefield experiences of World War I had an enormous impact on English literature. A number of poets serving in the British Army expressed their disillusionment with conventional patriotic ideas and imagery. Their poetry describes scenes of warfare with unusual realism. Siegfried Sassoon and Wilfred Owen were among the most important of these war poets. Owen, like Brooke, died in the war.

The destructiveness of the war left many people with the feeling that society was falling apart. T. S. Eliot best summarized their despair in *The Waste Land* (1922), the most influential poem of the period. Its jagged style, complex symbols, and references to other literary works set a new pattern for poetry. Eliot was conservative in politics and religion. But W. H. Auden, Stephen Spender, and Cecil Day-Lewis expressed radical political ideals in their verse. All three criticized injustices they saw in an unequal society. For all of these poets, society suffered from feelings of rootlessness and isolation.

Hugh MacDiarmid was a Scottish nationalist and political radical who wanted to capture a specifically Scottish cultural identity in his poetry. Dylan Thomas became the greatest Welsh poet of the 1900's. Thomas was known for his lyrical poems, which expressed his passionate love of life in vivid and melodious verse.

Fiction between the wars. Virginia Woolf remained the outstanding novelist of this period until her death in 1941. Another important novelist was D. H. Lawrence. He explored relationships between men and women in *Women in Love* (1920) and other autobiographical novels. Ford Madox Ford described changes in English society after World War I in four novels titled *Parade's End* (1924-1928). Graham Greene wrote about people troubled by difficult moral or religious problems in *The Power and the Glory* (1940) and other novels.

Several writers wrote humorous, satirical novels. Evelyn Waugh satirized wealthy and fashionable young people in *Vile Bodies* (1930) and *A Handful of Dust* (1934). Aldous Huxley also made fun of fashionable society in *Crome Yellow* (1921) and *Point Counter Point* (1928). But Huxley's best-known novel is *Brave New World* (1932), which describes a terrifying future society that eliminates individuality and personal liberty.

Literature after World War II. After World War II, the United Kingdom gradually lost most of its overseas empire. A sense of shrinking power in the world contributed to the anger and pessimism of much English literature in the years following the war. At the same time, many authors from the former English colonies settled in the United Kingdom and made important and original

contributions to English literature.

Writers from the pre-war period, such as Greene and Auden, continued to produce important works after World War II. George Orwell began his literary career in the 1930's, but his most famous novel, *1984,* appeared in 1949. This frightening story describes a future society that distorts truth and deprives the individual of privacy.

During the 1950's, a number of younger writers expressed their discontent with traditional English politics, education, and literature. These writers were labeled the *Angry Young Men.* They included the playwright John Osborne and the novelist John Braine. Osborne's drama *Look Back in Anger* (1956) describes a young working-class man's resentment of the English class system. In *Room at the Top* (1957), Braine created an ambitious working-class hero who has little respect for traditional English ways of life. Kingsley Amis's novel *Lucky Jim* (1954) satirized the self-satisfied and pretentious society of an English university.

Amis was also associated with the Movement, a name given to a group of writers in the 1950's who shared an interest in bringing clarity, restraint, and traditional craftsmanship to their writing. The Movement included novelists and playwrights, but the term usually refers to poets. The leading Movement poet was Philip Larkin. He combined traditional lyric forms with modern, everyday, and sometimes even vulgar vocabulary. Many of his poems explore change, loss, and death. Larkin grew increasingly conservative in later years. He and Amis were typical of several post-war British writers who felt great unease at the changes in British society following the loss of its empire.

Several authors wrote about such changes in society in multivolume works that follow many characters over a long period. Anthony Powell wrote 12 novels titled *A Dance to the Music of Time* (1951-1975). They portray upper middle-class society from the 1920's to the 1970's. Paul Scott wrote about the final years of British rule in India in the four-volume *Raj Quartet* (1966-1975). Doris Lessing wrote a five-volume *Children of Violence* (1952-1969). It deals with a British woman who grows up in Rhodesia (now Zimbabwe), moves to England, and becomes involved in radical politics.

William Golding wrote one of the most disturbing novels of the 1950's, *Lord of the Flies* (1954). In the novel, a group of English schoolboys are marooned on a deserted island and establish a rule of violence and terror.

Harold Pinter was the most important playwright of the postwar period. He wrote comic dramas that seem commonplace on the surface but have an underlying sense of menace. His most important early plays are *The Caretaker* (1960) and *The Homecoming* (1965). In the 1960's, Joe Orton wrote several farces, including *Entertaining Mr. Sloane* (1964) and *Loot* (1966) that dealt with sexual themes that had never before been treated so openly on the English stage.

English literature today

Recent English poetry has moved away from the restraint and traditionalism of the Movement. One of the period's most important poets, Ted Hughes, wrote on darker, mythical subject matter. His poetry often includes violent imagery, as in *Crow* (1970). In 1998, shortly before his death, Hughes published *Birthday Letters,* a group of poems looking back on his failed marriage to American poet Sylvia Plath.

Geoffrey Hill writes difficult, complex verse that often focuses on religious and historical themes. Douglas Dunn's earliest poetry shows the influence of Larkin. However, some of his later work moves toward fantastic and Scottish-influenced themes. Linton Kwesi Johnson's poetry combines the rhythms of English verse with those of Caribbean music and slang. This combination, called *dub,* has influenced many young black British writers. Fred D'Aguiar's verse collection *British Subjects* (1993) emphasizes how Caribbean experience and culture have become part of recent British cultural identity.

Recent English fiction. During the 1960's and 1970's, Iris Murdoch, Muriel Spark, and Anthony Burgess emerged as important novelists. Murdoch was a professor of philosophy who often treated questions of moral philosophy in her fiction. Spark's novels are often comic but with disturbing and even Gothic undertones. Burgess wrote experimental novels of great verbal complexity and wit. In *A Clockwork Orange* (1962), he told the story of a violent juvenile delinquent who is brainwashed into numb social conformity.

More recent significant English novelists have often come from the United Kingdom's different immigrant communities. They include Salman Rushdie from India, Kazuo Ishiguro from Japan, and Caryl Phillips from the Caribbean. Rushdie is the outstanding figure of this group. His writing has been described as an example of *magic realism,* a style that combines realism with fantastic or apparently supernatural events. His novels overflow with multiple characters and stories. Ishiguro's novels offer subtle psychological explorations of memory and history. Phillips's novels show the experience of ethnic hatred, slavery, and exile through the use of historical settings and multiple narrators,.

Other notable English novelists include A. S. Byatt, Pat Barker, and Martin Amis, the son of Kingsley Amis. Byatt's novels often develop through clever references to other works of literature and art. Barker's *Regeneration* trilogy (1991-1995) is based on the experiences of a psychologist who worked with soldiers during World War I. Many of Amis's novels treat violent and controversial subject matter.

Recent English drama. Harold Pinter continued to write highly individual plays. Many of his later dramas deal with power relationships among friends or lovers. Tom Stoppard writes original and complex plays with philosophical themes. His works often experiment with imaginary historical situations and are remarkable for their verbal brilliance. Peter Shaffer has written a number of plays about the psychology of artists, outsiders, and nonconformists.

Several playwrights have engaged political issues in their work. Edward Bond has written plays about class conflict and oppression throughout British history. Caryl Churchill draws on such themes as the connection between colonial and sexual oppression in British history. David Hare has examined key British institutions—the Anglican church, the legal system, and political parties—in three related plays. In *Amy's View* (1997), Hare reflected on differences between theater and the newer, more popular media of film and television. D. E. White

Related articles. For a list of British playwrights, see the *Re-*

lated articles in Drama. For a list of British poets, see the *Related articles* in Poetry. See also:

Old English literature (500-1100)

Alfred the Great	Bede, Saint
Anglo-Saxon Chronicle	Beowulf
Anglo-Saxons	

Middle English literature (1100-1485)

Arthur, King	Guy of Warwick	Morality play
Brut	Malory, Sir Thomas	Mystery play
Canterbury Tales	Miracle play	Robin Hood
Geoffrey of Monmouth		Round Table

The beginning of Modern English (1485-1603)

Bacon, Francis	Greene, Robert	More, Saint Thomas
Caxton, William	Jonson, Ben	Nashe, Thomas
Gascoigne, George	Lyly, John	

The early and middle 1600's

Metaphysical poets	Walton, Izaak
Milton, John	

Restoration literature (1660-1700)

Behn, Aphra	Butler, Samuel (1613-1680)	Pepys, Samuel
Bunyan, John		Restoration

The Augustan Age (1700-1750)

Addison, Joseph	Fielding, Henry	Robinson Crusoe
Age of Reason	Gay, John	Smollett, Tobias G.
Burke, Edmund	Gulliver's Travels	Steele, Sir Richard
Classicism	Richardson, Samuel	Sterne, Laurence
Defoe, Daniel		Swift, Jonathan

The Age of Johnson (1750-1784)

Boswell, James	Chesterfield, Earl of	Goldsmith, Oliver
Burke, Edmund		Johnson, Samuel
Burney, Fanny		

Romantic literature (1784-1832)

Austen, Jane	Gothic novel	Scott, Sir Walter
De Quincey, Thomas	Hazlitt, William	Shelley, Mary W.
Frankenstein	Lamb, Charles	Thomson, James
	Romanticism	Walpole, Horace

Victorian literature (1832-1901)

Brontë sisters	Eliot, George	Pater, Walter Horatio
Bulwer-Lytton, Edward G. E. L.	Gaskell, Elizabeth	Pre-Raphaelite Brotherhood
Butler, Samuel (1835-1902)	Gissing, George R.	Ruskin, John
Carlyle, Thomas	Haggard, H. Rider	Stevenson, Robert Louis
Carroll, Lewis	Hardy, Thomas	Stoker, Bram
Collins, Wilkie	Holmes, Sherlock	Thackeray, William Makepeace
Dickens, Charles	Hughes, Thomas	Trollope, Anthony
Doyle, Arthur Conan	Kingsley, Charles	Wilde, Oscar
Dracula	Kipling, Rudyard	
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Literature before and after the world wars

Ambler, Eric	Clarke, Arthur C.	Fleming, Ian L.
Amis, Kingsley	Compton-Burnett, Ivy	Ford, Ford Madox
Barrie, J. M.	Conrad, Joseph	Forester, Cecil Scott
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Bennett, Arnold	Dahl, Roald	Golding, William
Bowen, Elizabeth	Douglas, Norman	Greene, Graham
Buchan, John	Du Maurier, Daphne	Heyer, Georgette
Cary, Joyce	Durrell, Lawrence	Hilton, James
Chesterton, G. K.		
Christie, Agatha		
Hudson, William H.	Mansfield, Katherine	Sillitoe, Alan
Huxley, Aldous	Maugham, W. Somerset	Sitwell, Edith
Isherwood, Christopher	Munro, Hector Hugh	Snow, C. P.
Knight, Eric	Orczy, Baroness	Strachey, Lytton
Larkin, Philip	Orwell, George	Tolkien, J. R. R.
Lawrence, D. H.	Powell, Anthony	Walpole, Hugh Seymour
Lawrence, T. E.	Priestley, John B.	Waugh, Evelyn
Leavis, F. R.	Sackville-West, Victoria M.	Wells, H. G.
Lessing, Doris	Sayers, Dorothy L.	West, Rebecca
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		Woolf, Virginia

English literature today

Burgess, Anthony	James, P. D.	Rushdie, Salman
Deighton, Len	Le Carré, John	Spark, Muriel
Drabble, Margaret	Murdoch, Iris	

Other related articles

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Bloomsbury Group	Irish literature	Science fiction
Criticism	Literature for children	Scotland (The arts)
Detective story	Minstrel	Sonnet
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Outline

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Questions

What was the Augustan Age in English literature?
Who were the *Angry Young Men?*
Why is Samuel Richardson significant in English literature?
What were some characteristics of Old English poetry?
What subjects did Victorian writers deal with?

How did Geoffrey Chaucer influence English poetry?
What is a *sonnet?* A *sonnet sequence?*
Who was the leading Preromantic poet?
When was heroic tragedy important in English drama?
What was the Movement in modern English literature?

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English setter is a popular dog because of its handsome face and sleek coat. Its hunting skill also makes it a popular gundog. The setter has a fairly long, flat coat, colored white, black, and tan or in mixtures of white, black, lemon, orange, and chestnut. Long hairs called *feathers* cover the dog's legs and tail. Many owners prefer setters that have a white coat with little flecks of color instead of coats with large, solid-colored patches. The setter is quick and graceful and has a fine sense of smell. It shows where game is by pointing with its nose toward the game. It also may lift one of its front paws. An English setter stands about 25 inches (64 centimeters) high and weighs from 50 to 70 pounds (23 to 32 kilograms).

Critically reviewed by the English Setter Association of America

See also **Dog** (picture: Sporting dogs).

English sparrow. See **House sparrow.**

English springer spaniel is a sporting dog that forces game to spring from hiding places. Hunters use this dog more often than the cocker spaniel because it is larger and stronger. It stands about 18 to 21 inches (46 to 53 centimeters) high at the shoulder and weighs from 37 to 55 pounds (17 to 25 kilograms). The dog's coat is fairly long and grows thick enough to resist water and brambles. The coat may be reddish-brown and white, black and white, or a combination of white, tan, and black or reddish-brown. The dog is also a popular pet. See also **Dog** (picture: Sporting dogs).

Critically reviewed by the English Springer Spaniel Field Trial Association

English toy spaniel is a breed of dog that was a favorite with English nobility in the 1600's. It weighs from 9 to 12 pounds (4 to 5.4 kilograms) and has a round head, with a short, turned-up nose. The dog's silky coat grows thickly, with longer fringes of hair on the chest, legs, tail, and feet. There are four varieties of English toy spaniels. The *King Charles* is black and tan. The *Prince Charles* is black, tan, and white. The *Blenheim* is red and white, and the *Ruby* is solid red.

Critically reviewed by the English Toy Spaniel Club

Engraving is a process of *incising* (cutting) a design or image into a flat metal plate. The engraved plate is then used to print the design. Engraving has importance both in the fine arts and in commercial printing. This article discusses engraving as a fine art. For information about engraving in commercial printing, see **Photoengraving and photolithography.**

Engraving the plate. Most plates used in engraving are made of copper or zinc. To engrave an image into the plate, the artist uses a *burin,* a slim bar of tempered steel. One end of this tool is cut and sharpened to a 45-degree angle. The other end is set into a round wooden handle.

Engraving a plate requires great skill and patience. With one hand, the artist slowly and carefully moves the plate against the point of the burin. At the same time, the artist uses the other hand to guide and drive the burin in the desired direction. The depth and width of the incisions help determine the appearance of the line and thus the character of the picture. The artist removes the metal shavings from the incisions with a scraper. Lines can be altered or erased with special tools and materials. The artist can even eliminate all the incisions and begin a new engraving on the same plate.

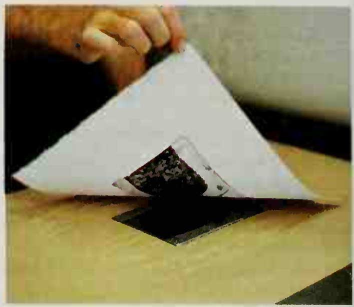
Printing the engraving also requires considerable skill because the artist wants to produce pictures that are as identical as possible. Each picture *pulled* (printed) from a single plate is called an *impression.* To pull an impression, the artist needs ink, paper, and a press. First the engraved plate is warmed over an appliance called a hot plate. The heated metal holds the thick printing ink more firmly than cold metal could. A piece of cardboard or a small roller is then used by the artist to put a layer of ink on the engraved surface. The artist rubs and pushes the ink across the plate, forcing ink into the incisions.

After the incisions have been filled with ink, the plate is wiped several times with a pad of stiff fabric. The artist wipes in a circular motion, varying the pressure to distribute the ink evenly over the entire plate. Additional wiping eliminates all except a thin film of ink from the plate's surface. The plate is usually wiped a final time with the hand to create highlights and delicate tonal effects. The plate is then ready for the press.

Walter Chandoha

The English toy spaniel has a long, silky coat.





WORLD BOOK photos by Dan Miller

Making an engraving. The artist cuts a design into a metal plate, *left,* with a sharp tool called a *burin.* Then ink is put on the plate, *center.* The artist runs the inked plate and a piece of paper through a press. The ink transfers onto the paper, creating the finished print, *right.*

Artists usually print engravings on handmade paper because of its superior quality. They soak or sponge the paper with water so it becomes more pliable and receives the ink better. They then adjust the press to obtain the desired pressure from the metal roller. They place the plate on the press and put the dampened paper on the inked plate. Next, they cover the paper with two or more felt blankets and run the plate through the press. The pressure of the roller causes the ink to transfer onto the paper, creating an impression or print.

After the plate has passed through the press, the artist removes the blankets and carefully lifts the paper so that it does not tear. The freshly pulled impression is placed between white blotters to dry. The artist puts flat boards on the blotters to make sure that the paper lies flat and does not wrinkle. Inking and printing are repeated for each impression. After pulling the impressions, the artist removes all ink from the plate with turpentine and carefully wraps and stores the plate.

Dry point is a variation of the basic engraving process. Like engraving, dry-point prints are made by cutting a design into a metal plate. But instead of a burin, the artist uses a metal tool called a *needle* with a diamond or hard steel point. As the needle cuts into the plate, it throws up a soft ridge of metal called a *burr.* Depending on the angle, the artist can create a burr on one or both sides of the incision. The burr, rather than the incision, holds the ink and thus forms the lines of the image. Dry-point plates are printed in the same way as other engraved plates. Dry-point lines are softer than those in burin engravings. Dry point is often combined with etching and engraving to obtain special effects.

History. Engraving ranks as one of the earliest forms of artistic expression. The first engravings were carved during prehistoric times. The oldest surviving metal engravings date back to the 1400's.

The German artist Albrecht Dürer, who lived from 1471 to 1528, became the first great engraver. Other

Madonna and Child (about 1470) by Andrea Mantegna; the Metropolitan Museum of Art, New York City, Elisha Whittelsey Fund, 1952

A Renaissance engraving by Andrea Mantegna of Italy has the solid quality of a statue. The artist captured this sculptural feeling by shading the folds of the robe with parallel lines.

Detail of *The Two Sisters* (1932) by Étienne Cournault; Bibliothèque Nationale, Paris (Mme. Simon-Cournault)

A modern engraving shows how texture can be created. The French artist Étienne Cournault produced different textures in a small area through concentrations of dots, dashes, and lines.

early masters included Martin Schongauer of Germany, Lucas Van Leyden of the Netherlands, and Andrea Mantegna and Antonio Pollaiuolo of Italy. William Hogarth was a leading English engraver of the 1700's. William Blake of England was a major engraver in the 1800's. The leading engravers of the 1900's included Stanley William Hayter and Gabor Peterdi. Andrew J. Stasik, Jr.

Related articles in *World Book* include:

Blake, William	Intaglio	Schongauer, Martin
Dürer, Albrecht	Mantegna, Andrea	Van Leyden, Lucas
Etching	Printing	
Hogarth, William		

Engraving and Printing, Bureau of, designs, engraves, and prints the paper money and postage stamps issued by the United States government. The bureau also makes commissions, certificates, permits, and internal revenue and customs stamps. It produces hundreds of other kinds of United States government security documents as well, including Treasury bills, bonds, and notes. The bureau also helps other federal agencies design and print documents that require safeguards against counterfeiting. These documents include military identification cards and other items.

The bureau is a division of the Department of the Treasury in Washington, D.C. It is the world's largest printer of security documents, producing many billions of items each year. Congress passed legislation authorizing the bureau's work in July 1862. A director appointed by the secretary of the Treasury heads the bureau.

Critically reviewed by the Bureau of Engraving and Printing

See also Money (How money is manufactured).

Enid, *EE nihd* (pop. 47,045; met. area pop. 57,813), a city in north-central Oklahoma, is the center of a wheat-growing district (see **Oklahoma** [political map]). Enid has grain elevators and flour mills, including the largest flour mill in the state. The city produces portable drilling equipment and processed meat products. Northern Oklahoma College and Northwestern Oklahoma State University have campuses in Enid. The city is the home of Vance Air Force Base. Enid was incorporated in 1894. It is the seat of Garfield County, and it has a council-manager form of government. Kevin Hassler

Eniwetok. See Enewetak.

Enlightenment. See Age of Reason.

Enright, Elizabeth (1909-1968), was an American author who is best known for her books for children. She won the 1939 Newbery Medal for *Thimble Summer* (1938), a story of life on a Wisconsin farm in summer. Her other books include *Kintu: Congo Adventure* (1935), *The Saturdays* (1941), *Gone-away Lake* (1957), and *Tatsinda* (1963). Enright also wrote adult books. She illustrated most of her own works. Enright was born on Sept. 17, 1909, in Oak Park, Illinois. Virginia L. Wolf

Enron Corporation was once one of the world's largest energy companies. In November 2001, Enron revealed that it had overstated its earnings by several hundred million dollars since 1997. The following month, Enron filed one of the largest corporate bankruptcy claims in United States history. The financial collapse led to numerous investigations into complicated financial transactions and accounting procedures by both Enron and Arthur Andersen, Enron's accounting firm. Investigators focused on charges that Enron deliberately concealed its financial problems from investors. Arthur Andersen admitted to destroying documents that might have been significant to the Enron investigations.

Prior to the company's downfall, some top Enron executives sold their shares of company stock. However, Enron's employees were not allowed to sell shares from their retirement accounts for several weeks as the stock dropped in value. As a result, thousands of employees lost much of their retirement savings. Many of these employees and other shareholders brought lawsuits against Enron officials, and against Arthur Andersen. In addition, because Enron and some of its executives contributed money to politicians, some people charged that Enron received special treatment from the U.S. government. In January 2002, Kenneth L. Lay, Enron's founder, resigned as the company's chairman.

Enron originated with the 1985 merger of Houston Natural Gas and InterNorth of Omaha, Nebraska. Based in Houston, Enron evolved from a utility that produced and transported natural gas into a successful energy trading firm. Before its collapse, Enron was, according to some calculations, the seventh largest U.S. corporation. James R. Barth

Ensor, James (1860-1949), was a Belgian painter and printmaker. He created his most important pictures between 1880 and 1900. Masks were a favorite subject. His figures often wear brightly colored but devilish masks that serve to both threaten the viewer and hide the wearer's identity. Skeletons and demons also appear in many of Ensor's paintings and etchings. In his most famous painting, *The Entry of Christ into Brussels* (1888), Ensor combined three of his most common themes—the

Detail of *Demons Tormenting Me* (1888), a pencil and black chalk drawing; The Art Institute of Chicago, the Ada Turnbull Hertle Fund

A self-portrait of James Ensor is featured in this drawing. Ensor included images of demons and freakish figures in many of his works.

mask, the crowd, and Jesus Christ.

Ensor's fantastic subjects have been compared to the paintings of two earlier Belgian artists, Pieter Bruegel the Elder and Hieronymus Bosch. His paintings also anticipate two art movements of the early 1900's—Expressionism and Surrealism.

Ensor was born on Oct. 13, 1860, in Ostend, a resort town on the North Sea. His paintings reflect the carnival masks, toys, and sea shells that his parents sold from their souvenir shop to the tourists. Pamela A. Ivinski

Entomology, *EHN tuh MAHL uh jee,* is a major branch of zoology concerned with the study of insects. People who specialize in insects are called *entomologists.* In addition, these scientists study related animals, such as ticks, mites, spiders, and centipedes. Such animals and the insects are types of *arthropods* (see **Arthropod**). Entomology developed rapidly after the 1750's, when the Swedish naturalist Carolus Linnaeus provided a useful system of classifying and naming plants and animals (see **Linnaeus, Carolus; Insect** [The orders of insects; table]).

What entomologists study. Entomologists investigate the anatomy, physiology, development, life history, behavior, ecology, and classification of insects and related arthropods. There are about 1 $\frac{1}{2}$ million species of these animals.

Insects are one of humanity's chief competitors for food and fiber. For example, from 1925 to 1958, grasshoppers destroyed about $800 million worth of agricultural crops and $2 billion worth of range grass in the United States.

Most entomologists work in the field of *economic entomology,* also called *applied entomology.* They study insect pests that damage crops, ornamental plants, stored products, and buildings, or that endanger the health of human beings and animals. *Agricultural entomologists* study insect pests of food and fiber. *Forest entomologists* study pests of timber. *Medical entomologists* and *veterinary entomologists* seek to decrease the threat of insects that cause injury or disease to people and animals. Scientists reduce the numbers of insect pests through a variety of controls. These include cultural controls, such as the draining of swamps where mosquitoes breed; chemical controls, such as the use of insecticides and insect repellents; and biological controls, such as the use of animals that naturally prey on insect pests.

Many insects are beneficial to people. Silkworms contribute a valuable fiber. Honey bees not only produce honey and beeswax, they also pollinate many kinds of plants. Some insects, such as praying mantises, ladybird beetles, and lacewings, prey on many insect pests. Entomologists seek to protect these helpful species and increase their numbers.

Careers in entomology. Students who wish to pursue a career in entomology must have at least a bachelor's degree in entomology or biology. Most teaching and research positions require a master's or doctor's degree in entomology from an agricultural university. Entomologists are employed by state and federal agricultural experiment stations, and in public health agencies. They may also work for universities or museums. Some work in industry, particularly in companies that produce pesticides. Charles V. Covell, Jr.

See also **Insect; Insecticide; Swammerdam, Jan.**

Entrepreneur. See **Industrial Revolution** (Life before the Industrial Revolution).

Entropy, *EHN truh pee,* is a measure of the amount of disorder or randomness in a system. Because there are many more random ways of arranging a group of things than there are organized ways, disorder is much more probable. For example, shuffling a deck of cards always leads to a jumbled distribution of cards, and never to an ordered sequence.

The idea of entropy is the basis of the second law of thermodynamics. According to this law, the direction of spontaneous change in isolated systems is toward maximum disorder. Thus, heat flows of its own accord only from a hotter substance to a cooler one. As the cooler substance gains heat, the motion of its molecules becomes more disorderly and its entropy increases (see **Heat** [Disorder]).

Furthermore, a gas will always expand to fill its container but will never contract to occupy only a fraction of the container. The entropy of the gas increases as the gas expands because more positions are available for the molecules to occupy. Every substance has greater entropy as a gas than as a liquid.

Some changes may decrease entropy in one system. But this decrease is more than offset by an entropy increase in connected systems. For example, the entropy of water decreases as the liquid freezes, but the heat released in the process increases the entropy of the surrounding air.

The entropy of a substance increases whenever the substance loses some of its ability to do work. For example, air forced into an empty balloon has low entropy because the air molecules are compressed in a small volume. The compressed air does work by expanding to inflate the balloon. In the inflated balloon, the molecules can occupy a larger number of positions and thus have greater entropy. But they have lost the ability to do more work by expanding the balloon further.

Taken together, all processes occurring now will result in a universe of greater disorder. Because the entropy of the universe is always increasing, a state of greater entropy must be one that occurs later in time. For this reason, entropy has been called "time's arrow."
Melvyn C. Usselman

Enunciation. See **Pronunciation.**

Envelope is a piece of folded, sealed paper. It serves as a wrapper to hold letters and other papers to be mailed, or acts as protection against loss or damage. Envelopes are made of a single sheet of paper folded so that one flap remains open. This flap is gummed so the envelope may be sealed after the letter or papers have been inserted. Self-sealing envelopes make use of a gum that need not be moistened to stick.

Envelopes were first manufactured in 1839 by a New York City man named Pierson. Before that time, all letters were folded so that a blank portion of the paper could be used for the address. The edges of the paper were sealed with sealing wax. For about 10 years after envelopes were invented, they were cut, folded, and pasted by hand. A worker could make about 3,000 envelopes a day. The first successful machine for making envelopes was patented in 1849 by J. K. Park and C. S. Watsen of New York City. A greatly improved envelope machine, patented in 1898 by John Ames Sherman,

lowered the cost of making gummed envelopes.

Envelopes are numbered from 5 to 14 according to size. The No. 10 envelope is the most popular size for business letters. It measures 9 $\frac{1}{2}$ inches (24.1 centimeters) long and 4 $\frac{1}{8}$ inches (10.5 centimeters) wide.

Some standardization of envelope sizes is necessary for the efficient operation of mechanical mail-sorting devices. The U.S. Postal Service requires that envelopes sent through the mail be rectangular and no smaller than 5 inches (12.7 centimeters) long and 3 $\frac{1}{2}$ inches (8.9 centimeters) wide. The Universal Postal Union, a United Nations agency, has a metric size range to make the handling of international mail more efficient. Envelopes should be at least 14 centimeters (5 $\frac{1}{2}$ inches) long and 9 centimeters (3 $\frac{1}{2}$ inches) wide, but no more than 23.5 centimeters (9 $\frac{1}{4}$ inches) long and 12 centimeters (4 $\frac{2}{3}$ inches) wide. Larry L. Graham

Environment is everything that is external to an organism. A human being's environment includes such factors as temperature, food supply, and other people. A plant's environment may be made up of soil, sunlight, and animals that will eat the plant. Nonliving environmental factors, such as temperature and sunlight, make up the *abiotic environment.* Living or recently living things, such as seaweed and food, make up the *biotic environment.* Both the abiotic and biotic environments interact to make up the total environment of living or nonliving things.

Abiotic environment includes such factors as soil, water, atmosphere, and radiation. The abiotic environment is made up of many objects and forces that influence one another and influence the surrounding community of living things. For example, a river's current, temperature, clearness, and chemical composition will influence what kinds of plants and animals live there and how they live.

One important group of abiotic environmental factors make up what is called the weather. Living and nonliving things are influenced by rain, snow, hot or cold temperature, evaporation of water, *humidity* (amount of water vapor in the air), wind, and numerous other weather conditions. Many plants and animals die each year because of weather conditions. Human beings build homes and wear clothes to protect themselves from harsh climates. They study the weather in order to learn how to control it.

Other abiotic factors include the amount of living space and certain *nutrients* (nourishing substances) available to an organism. All organisms need a certain amount of space in which to live and carry on community relationships. They also must have nonliving nutrients, such as phosphorus, to maintain such body activities as circulation and digestion. *Ecology* is the study of the relationships between organisms and their environment.

Biotic environment includes food, plants, animals, and their interactions among one another and the abiotic environment. A human being's survival and well-being depend largely on the foods eaten, such as fruit, vegetables, and meat. They also depend on an individual's associations with other living things. For example, some bacteria in the digestive tract help a person digest certain foods.

Social or cultural surroundings are an important part of a person's biotic environment. A highly developed nervous system has made possible memory, reason, and communication. Human beings teach one another what they have learned. By passing on knowledge, people have developed religion, art, music, literature, technology, and science. The cultural inheritance and biological inheritance of human beings have enabled them to advance beyond any animal in controlling their environment. They are now exploring the environment of outer space. Lawrence C. Wit

Related articles in *World Book* include:

Adaptation
Biome
Child (Individual differences)
Ecology
Engineering (Environmental engineering)
Environmental pollution
Gaia
Heredity (Heredity and environment)
Personality

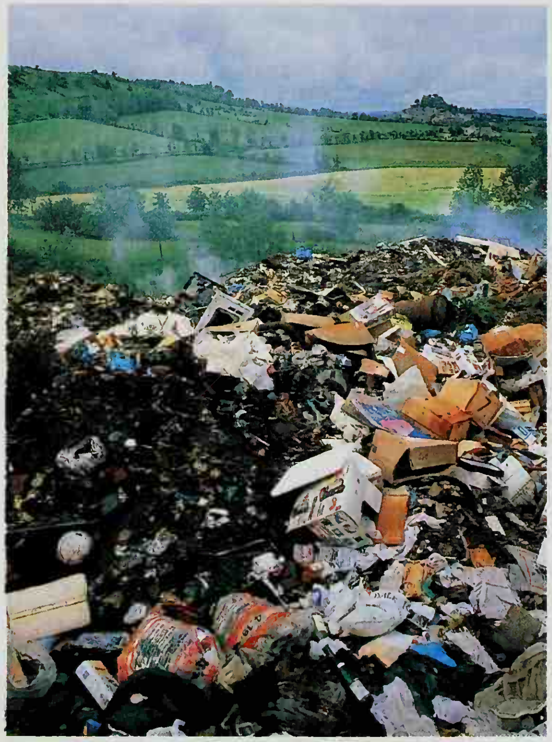
Environmental Defense Fund is a private organization in the United States that works to protect the environment. It has achieved many of its goals through legal action. The organization sues private companies and federal, state, and local government agencies to make them stop polluting the environment. Its cases are based on the belief that Americans have a constitutional right to a healthy environment.

A lawsuit by the fund strongly influenced the government's 1972 decision to gradually phase out all uses of DDT, an insecticide. Other suits caused companies and government agencies to abandon or modify a number of projects that could have harmed the environment. These projects included the construction of canals, dams, and highways. A group of lawyers and scientists founded the fund in 1967. It has headquarters in New York City. Alan McGowan

Environmental impact statement is a report that evaluates all planned projects or programs which might seriously affect the environment. Such a report must be issued by any agency of the United States government that plans to build various facilities, including dams, highways, and power plants. A federal agency also must issue a report for any large state, local, or private project that it will regulate or support financially. The publication of environmental impact statements is required by the National Environmental Policy Act, which became law in 1970.

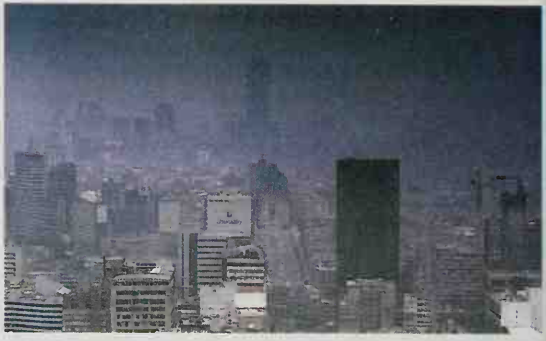
The purpose of an environmental impact statement is to make a federal agency consider the possible environmental damage that might result from a project under its jurisdiction. The federal agency must also consider alternatives to the project under consideration. The agency itself then decides whether to allow the project to proceed or whether to alter or abandon it. It bases its decision on certain federal guidelines. For example, before building a highway, an agency must study how pollution from vehicles using it will affect the area. The agency prepares a preliminary environmental impact statement and submits it to federal, state, and local agencies, as well as the general public. After reviewing their reactions, the agency issues a final report and makes its decision.

Environmental impact statements sometimes have been used by individuals and groups in filing lawsuits to delay or stop projects they consider harmful. Such projects include the drilling of oil wells and the construction of harbors and power plants. Alan McGowan



Peter Cade, Tony Stone Images

Solid waste in France



Sergio Dorantes, Sygma

Air pollution in Mexico City

Bob Stern, Gamma/Liaison

Water pollution in Estonia

Environmental pollution is one of the most serious problems facing the world today. It threatens the health of all living things and damages the natural beauty of the earth.

Environmental pollution

Environmental pollution is a term that refers to all the ways that human activity harms the natural environment. Most people have witnessed environmental pollution in the form of an open garbage dump or an automobile pouring out black smoke. However, pollution can also be invisible, odorless, and tasteless. Some kinds of pollution do not actually dirty the land, air, or water, but they reduce the quality of life for people and other living things. For example, noise from traffic and machinery can be considered forms of pollution.

Environmental pollution is one of the most serious problems facing humanity and other life forms today. Badly polluted air can harm crops and cause life-threatening illnesses. Some air pollutants have reduced the capacity of the atmosphere to filter out the sun's harmful ultraviolet radiation. Most scientists believe that these and other air pollutants have begun to change climates around the world. Water and soil pollution threaten the ability of farmers to grow enough food. Ocean pollution endangers many marine organisms.

Marian R. Chertow, the contributor of this article, is Director of the Industrial Environmental Management Program at the Yale School of Forestry and Environmental Studies.

Many people think of air, water, and soil pollution as distinct forms of pollution. However, each of the parts of an environment—air, water, and soil—depends upon the others and upon the plants and animals living within the environment. All the living things in an environment and the nonliving things with which they interact make up an *ecosystem.* All the ecosystems of the earth are connected. Thus, pollution that seems to affect only one part of the environment may also affect other parts. For example, sooty smoke from a power plant might appear to harm only the atmosphere. But rain can wash some harmful chemicals in the smoke out of the sky and onto land or into waterways.

Some pollution comes from one specific point or location, such as a sewage pipe spilling dirty water into a river. Such pollution is called *point source pollution.* Other pollution comes from large areas. Water can run off farmland and carry pesticides and fertilizers into rivers. Rain water can wash gasoline, oil, and salt from highways and parking lots into the wells that supply drinking water. Pollution that comes from such large areas is called *nonpoint source pollution.*

Nearly everyone would like to have pollution reduced. Unfortunately, most of the pollution that now threatens the health of our planet comes from products that many people want and need. For example, automobiles provide the convenience of personal transportation, but they create a large percentage of the world's air pollution. Factories make products that people use and

enjoy, but industrial processes can also pollute. Pesticides and fertilizers aid in growing large quantities of food, but they also poison the soil and water.

To end or greatly decrease pollution, people would have to reduce use of cars and other modern conveniences, and some factories would have to close or change production methods. Because most people's jobs are dependent on industries that contribute to environmental pollution, shutting down these industries would increase unemployment. In addition, if farmers suddenly stopped using chemical fertilizers and pesticides, there might be less food to feed the people of the world.

Over time, however, pollution can be reduced in many ways without seriously disrupting people's lives. For example, governments can pass laws that encourage businesses to adopt less polluting methods of operation. Scientists and engineers can develop products and processes that are cleaner and safer for the environment. And individuals around the world can themselves find ways to reduce environmental pollution.

Types of pollution

The chief types of environmental pollution include air pollution, water pollution, soil pollution, pollution caused by solid waste and hazardous waste, and noise pollution.

Air pollution is the contamination of the air by such substances as fuel exhaust and smoke. It can harm the health of plants and animals and damage buildings and other structures. It can potentially cause a change in the worldwide climate. According to the World Health Organization, about 3 million people die each year as a result of air pollution.

The atmosphere normally consists of nitrogen, oxygen, and small amounts of carbon dioxide and other gases and *particulates* (tiny particles of liquid or solid matter). A number of natural processes work to keep the parts of the atmosphere in balance. For example, plants use carbon dioxide and produce oxygen. Animals, in turn, use up oxygen and produce carbon dioxide through respiration. Forest fires and volcanic eruptions shoot gases and particulates into the atmosphere, and rain and wind wash them out or scatter them.

Air pollution occurs when industries and vehicles release such large amounts of gas and particulates into the air that natural processes can no longer keep the atmosphere in balance. There are two chief types of air pollution: (1) outdoor and (2) indoor.

Outdoor air pollution. Each year, hundreds of millions of tons of gases and particulates pour into the atmosphere. Most of this pollution results from the burning of fuel to power motor vehicles and to heat buildings. Some air pollution also comes from business and industrial processes. For example, many dry cleaning plants remove dirt from clothing with a chemical called *perchloroethylene,* which is a hazardous air pollutant. The burning of garbage may discharge smoke and heavy metals, such as lead and mercury, into the atmosphere. Most heavy metals are highly poisonous.

One of the most common types of outdoor air pollution is *smog.* Smog is a brown, hazy mixture of gases and particulates. It develops when certain gases released by the combustion of gasoline and other petroleum products react with sunlight in the atmosphere. This reaction creates hundreds of harmful chemicals that make up smog.

One of the chemicals in smog is a toxic form of oxygen called *ozone.* Exposure to high concentrations of ozone causes headaches, burning eyes, and irritation of the respiratory tract in many individuals. In some cases, ozone in the lower atmosphere can cause death. Ozone can also damage plant life and even kill trees.

Particulates can also contribute to air pollution. Some particles of fossil fuels escape boilers in factories and engines in cars and trucks without undergoing complete *combustion* (burning). These particles pollute in many ways. They fall onto vegetation and the surfaces of buildings, dirtying them. Particulates can mix with other chemicals to create smog. They can also enter people's lungs and cause asthma or other diseases.

Acid rain is a term for rain and other precipitation that is polluted mainly by sulfuric acid and nitric acid. These acids form when gases called sulfur dioxide and nitrogen oxides react with water vapor in the air. These gases come chiefly from the burning of coal, gas, and oil by cars, factories, and power plants. The acids in acid rain move through the air and water and harm the environment over large areas. Acid rain has killed entire fish populations in a number of lakes. It has also damaged many buildings, bridges, and statues. Scientists believe high concentrations of acid rain can harm forests and soil. Regions affected by acid rain include large parts of eastern North America, Scandinavia, and central Europe.

Chemicals called *chlorofluorocarbons* (CFC's) are pollutants that destroy the ozone layer in the upper atmosphere. CFC's have been used as refrigerants in air conditioners and refrigerators and to make plastic foam insulation. Ozone, the same gas that is a harmful pollutant in smog, forms a protective layer in the upper atmosphere. It shields the earth's surface from more than 95 percent of the sun's ultraviolet radiation. As CFC's thin the ozone layer, more ultraviolet radiation reaches the surface of the earth. Overexposure to such radiation damages plants and greatly increases people's risk of skin cancer.

The *greenhouse effect* is the warming that results when the earth's atmosphere traps the sun's heat. It is created by carbon dioxide, methane, and other atmospheric gases, which allow sunlight to reach the earth but prevent heat from leaving the atmosphere. These heat-trapping gases are often called *greenhouse gases.*

Fuel burning and other human activities are increasing the amount of greenhouse gases in the atmosphere. Many scientists believe such an increase is intensifying the greenhouse effect and raising temperatures worldwide. This increase in temperature, called *global warming,* may cause many problems. A strong greenhouse effect could melt glaciers and Arctic ice, flooding coastal areas. It could also shift rainfall patterns, creating more droughts and severe tropical storms.

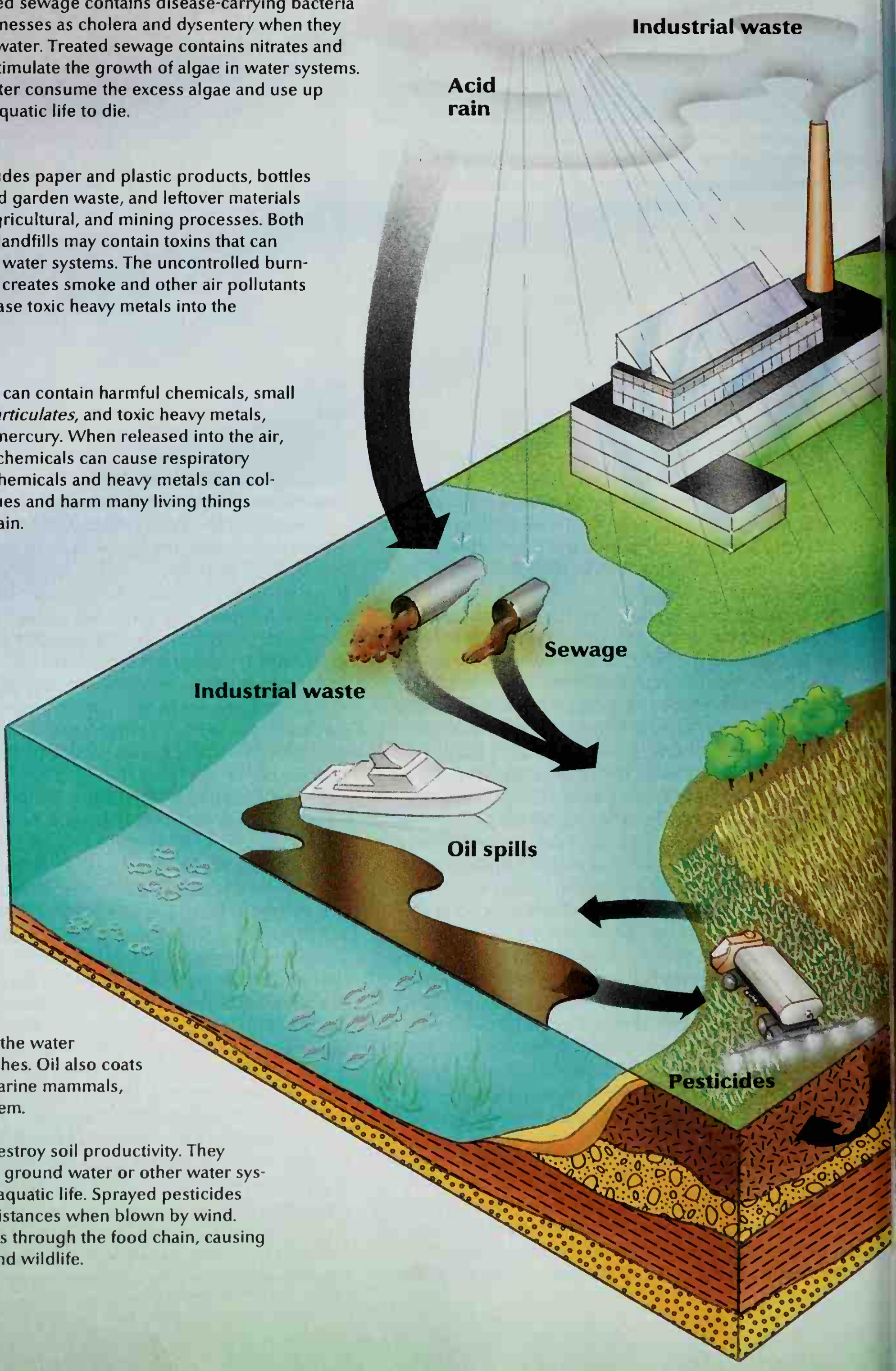
Indoor air pollution occurs when buildings with poorly designed ventilation systems trap pollutants inside. The main types of indoor pollutants are tobacco smoke, gases from stoves and furnaces, household chemicals, small fiber particles, and hazardous fumes given off by building materials, including insulation, glue, and paint. In some office buildings, high amounts of these sub-

Text continued on page 334

Kinds of environmental pollution

There are many kinds of environmental pollution that harm our planet in a wide variety of ways. Because all the parts of the environment are connected with one another, a pollutant that chiefly damages one natural system may also affect others.

WORLD BOOK illustration by Michael Yurkovic



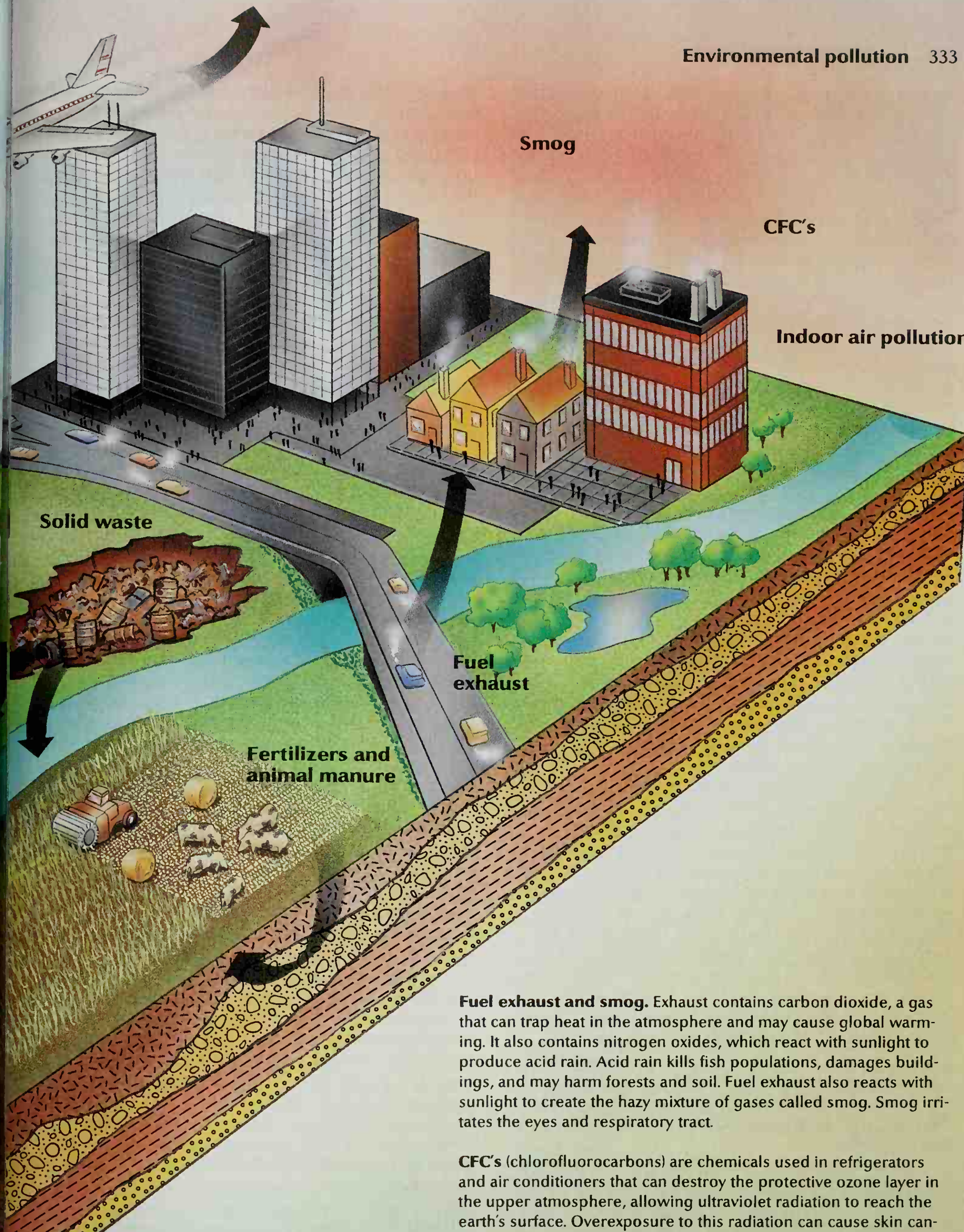
Sewage. Untreated sewage contains disease-carrying bacteria that cause such illnesses as cholera and dysentery when they get into drinking water. Treated sewage contains nitrates and phosphates that stimulate the growth of algae in water systems. Bacteria in the water consume the excess algae and use up oxygen, causing aquatic life to die.

Solid waste includes paper and plastic products, bottles and cans, food and garden waste, and leftover materials from industrial, agricultural, and mining processes. Both open dumps and landfills may contain toxins that can seep into soil and water systems. The uncontrolled burning of solid waste creates smoke and other air pollutants and may also release toxic heavy metals into the environment.

Industrial waste can contain harmful chemicals, small particles called *particulates*, and toxic heavy metals, such as lead and mercury. When released into the air, certain industrial chemicals can cause respiratory problems. Toxic chemicals and heavy metals can collect in animal tissues and harm many living things along the food chain.

Oil spills pollute the water and damage beaches. Oil also coats fish, birds, and marine mammals, killing many of them.

Pesticides can destroy soil productivity. They can also flow into ground water or other water systems and poison aquatic life. Sprayed pesticides can travel great distances when blown by wind. They can also pass through the food chain, causing harm to people and wildlife.



Fuel exhaust and smog. Exhaust contains carbon dioxide, a gas that can trap heat in the atmosphere and may cause global warming. It also contains nitrogen oxides, which react with sunlight to produce acid rain. Acid rain kills fish populations, damages buildings, and may harm forests and soil. Fuel exhaust also reacts with sunlight to create the hazy mixture of gases called smog. Smog irritates the eyes and respiratory tract.

CFC's (chlorofluorocarbons) are chemicals used in refrigerators and air conditioners that can destroy the protective ozone layer in the upper atmosphere, allowing ultraviolet radiation to reach the earth's surface. Overexposure to this radiation can cause skin cancer and damage plant life.

Indoor air pollution, including smoke and hazardous fumes given off by building materials, can cause health problems in people. Radon gas released by radioactive rocks beneath buildings can cause lung cancer if inhaled in large quantities.

Fertilizers and animal manure can run off into water systems and supply nutrients that stimulate excess algae growth.

stances cause headaches, eye irritation, and other health problems in workers. Such health problems are sometimes called *sick building syndrome.*

Radon, a radioactive gas given off through the decay of uranium in rocks within the earth, is another harmful indoor pollutant. It can cause lung cancer if inhaled in large quantities. People can be exposed to radon when the gas leaks into basements of homes built over radioactive soil or rock. Energy-efficient buildings, which keep in heated or cooled air, can trap radon indoors and lead to high concentrations of the gas.

Water pollution is the contamination of water by sewage, toxic chemicals, metals, oils, or other substances. Water pollution can affect such surface waters as rivers, lakes, and oceans, as well as the water beneath the earth's surface, called *ground water.* Water pollution can harm many species of plants and animals. According to the World Health Organization, nearly one-sixth of the world's people have no access to safe drinking water.

In a healthy water system, a cycle of natural processes turns wastes into useful or harmless substances. The cycle begins when organisms called *aerobic bacteria* use the oxygen dissolved in water to digest wastes. This digestion process releases nitrates, phosphates, and other *nutrients* (chemical substances that living things need for growth). Algae and aquatic green plants absorb these nutrients. Microscopic animals called *zooplankton* eat the algae, and fish eat the zooplankton. The fish, in turn, may be eaten by larger fish, birds, or other animals. These larger animals produce body wastes and eventually die. Bacteria break down dead animals and animal wastes, and the cycle begins again.

Water pollution comes from businesses, farms, homes, industries, and other sources. It includes sewage, industrial chemicals, agricultural chemicals, and livestock wastes. Water pollution occurs when people put so much waste into a water system that its natural cleansing processes cannot function properly. Some waste, such as oil, industrial acids, or farm pesticides, poisons aquatic plants and animals. Other waste, such as phosphate detergents, chemical fertilizers, and animal manure, pollutes by supplying excess nutrients for aquatic life. This pollution process is called *eutrophication.* It begins when large amounts of nutrients flow into a water system. These nutrients stimulate excessive growth of algae. As more algae grow, more also die. Bacteria in the water use up large amounts of oxygen consuming the excess dead algae. The oxygen level of the water then drops, causing many aquatic plants and animals to die.

Another form of water pollution is the clean but heated water discharged by power plants into waterways. This heated water, called *thermal pollution,* harms fish and aquatic plants by reducing the amount of oxygen in the water. In addition, it may affect fish that rely on seasonal temperature changes to locate their breeding grounds. Chemical and oil spills can cause devastating water pollution that kills water birds, shellfish, and other wildlife.

Some water pollution occurs when there is improper separation of sewer wastewater from clean drinking water. In parts of the world that lack modern sewage treatment plants, water carrying human waste can flow into drinking water supplies. Disease-carrying bacteria in the waste can then contaminate the drinking water and cause such illnesses as cholera and dysentery. In areas with good sanitation, most human waste flows through underground pipes to special treatment plants that kill the harmful bacteria and remove the solid waste.

Water pollution also occurs when chemicals seep through the ground and enter *aquifers,* areas where ground water is stored in porous rock. Such pollution is a concern because aquifers supply much of the drinking water and water for farms in some areas. The lack of oxygen in aquifers inhibits bacteria from breaking down contaminants, and the isolation of aquifers underground makes it difficult to locate and remove pollutants from them. Chemicals that enter ground water can remain there for long periods and continue to contaminate local water supplies.

Soil pollution is the destruction of the earth's thin layer of healthy, productive soil, where much of our food is grown. Without fertile soil, farmers could not grow enough food to support the world's people.

Healthy soil depends on bacteria, fungi, and small animals to break down wastes in the soil and release nutrients. These nutrients help plants grow. Fertilizers and pesticides can limit the ability of soil organisms to process wastes. As a result, farmers who overuse fertilizers and pesticides can destroy the soil's productivity.

A number of other human activities can also damage soil. The irrigation of soil in dry areas with poor drainage can leave water standing in fields. When this standing water evaporates, it leaves salt deposits behind, making the soil too salty for growing crops. Mining operations and smelters contaminate soil with toxic heavy metals. Many scientists believe acid rain can also reduce soil fertility.

Solid waste is probably the most visible form of pollution. Every year, people dispose of billions of tons of solid garbage. Industrial wastes account for the majority of the discarded material. Solid waste from homes, offices, and stores is called *municipal solid waste.* It includes paper, plastic, glass, metal cans, food scraps, and yard trimmings. Other waste consists of junked automobiles, scrap metal, leftover materials from agricultural processes, and mining wastes known as *spoil.*

The handling of solid waste is a problem because most disposal methods damage the environment. Open dumps ruin the natural beauty of the land and provide a home for rats and other disease-carrying animals. Both open dumps and *landfills* (areas of buried wastes) may contain toxins that seep into ground water or flow into streams and lakes. The uncontrolled burning of solid waste creates smoke and other air pollution. Even burning waste in incinerators can release toxic chemicals, ash, and harmful metals into the air.

Hazardous waste is composed of discarded substances that can threaten human health and the environment. A waste is hazardous if it *corrodes* (wears away) other materials; explodes; ignites easily; reacts strongly with water; or is poisonous. Sources of hazardous waste include industries, hospitals, and laboratories. Such waste can cause immediate injury when people breathe, swallow, or touch it. When buried in the ground or left in open dumps, some hazardous waste can contaminate air, ground water, and food crops.

The mishandling or accidental release of hazardous waste has caused a number of disasters around the world. For example, in 1978, hazardous chemicals leaking from a waste disposal site in the Love Canal area of western New York threatened the health of nearby residents. Hundreds of people were forced to abandon their homes. In 1984, a leak of poisonous gas from a pesticide plant in Bhopal, India, killed more than 2,800 people and caused eye and respiratory damage to more than 20,000.

Some hazardous waste can seriously harm the health of people, wildlife, and plants. These pollutants include radiation, pesticides, and heavy metals.

Radiation is an invisible pollutant that can contaminate any part of the environment. Most radiation comes from natural sources, such as minerals and the sun's rays. Scientists can also produce radioactive elements in their laboratories. Exposure to large amounts of radiation can harm cells and result in cancer.

Radioactive waste produced by nuclear reactors and weapons factories pose a potentially serious environmental problem. Some of this waste will remain radioactive for thousands of years. The safe storage of radioactive waste is both difficult and expensive.

Pesticides can travel great distances through the environment. When sprayed on crops or in gardens, pesticides can be blown by the wind to other areas. They can also flow with rain water into nearby streams or can seep through the soil into ground water. Some pesticides can remain in the environment for many years and pass from one organism to another. For example, when pesticides are present in a stream, small fish and other organisms can absorb them. Larger fish who eat these contaminated organisms build up even larger amounts of pesticides in their flesh. This process is called *bioaccumulation.*

Heavy metals include mercury and lead. Mining operations, solid waste incinerators, industrial processes, and motor vehicles can all release heavy metals into the environment. Like pesticides, they are long lasting and can spread through the environment. Also, like pesticides, they can collect in the bones and other tissues of animals. In human beings, heavy metals can damage bones, various internal organs, and the nervous system. Many can also cause cancer.

Noise pollution comes from such machines as airplanes, motor vehicles, construction machinery, and industrial equipment. Noise does not dirty the air, water, or land, but it can cause discomfort, anxiety, and hearing loss in human beings and other animals.

Controlling pollution

Controlling pollution depends on the efforts of governments, scientists, business and industry, agriculture, environmental organizations, and individuals.

Government action. In many countries around the world, governments work to help clean up pollution. Such environmental efforts come from both local and national governments. In addition, a number of international efforts have been made to protect the earth's resources.

Local efforts. Many local governments have enacted laws to help clean up the environment. For example, in 1989, California adopted a 20-year plan to reduce air pollution in the Los Angeles area, which had the worst air quality in the United States. The plan includes measures to restrict the use of gasoline-powered vehicles and to encourage the use of mass transportation.

Paul Howell, Gamma/Liaison

A government cleanup project called Superfund works to eliminate unsafe toxic waste dumps in the United States. Inspectors from the Environmental Protection Agency collect mud samples, *shown here,* to check for chemical contamination.

National efforts. Most countries have national pollution control agencies. In the United States, for example, the Environmental Protection Agency (EPA) sets and enforces pollution control standards. It also assists state and local governments with pollution control.

Many national governments pass legislation to help limit and prevent pollution. Some pollution control laws limit or ban the release of pollutants into the environment. In the United States, the Clean Water Act of 1972 and its amendments have reduced the discharge of untreated water and harmful chemicals into rivers and other waterways. The Resource Conservation and Recovery Act of 1976 requires that hazardous wastes be specially treated before disposal. The act also requires landfills to be constructed with double liners and collection systems to prevent hazardous chemicals from entering water supplies.

Some pollution prevention laws require that polluters be issued an *emission permit.* Such a permit limits the amount of a pollutant a facility can legally release. The Clean Water Act of 1972 requires facilities releasing pollutants into surface water to do so within the limits of a permit. If a facility releases pollutants without a permit or above the limits of its permit, it may receive a fine or be shut down.

Other laws are designed to clean up pollution. In 1980, for example, the U.S. Congress enacted the Comprehensive Environmental Response, Compensation, and Liability Act. This act, also known as "Superfund," began a government cleanup of hazardous waste dumps in the United States. This law and others hold polluters responsible for repairing the environmental damage they cause.

National governments may also levy taxes on the release of pollutants or substances that create pollution. Beginning in 1990, the United States imposed taxes on the use of CFC's to help phase out their production. High taxes gave companies an incentive to develop al-

AP/Wide World

Recycling helps prevent pollution by reducing the amount of solid waste that must be dumped or burned. At a computer recycling center, workers remove reusable components and materials from computer equipment cases, which are then crushed.

ternatives to CFC's in their processes. By 1996, the production of CFC's had ended in the United States. High gasoline taxes may encourage people to drive less, to carpool, and to use public transportation, thus reducing air pollution from automobiles.

The forces of a free market can be used to help control pollution. A national government may set a total amount of pollutant emissions allowed over all industries and permit companies to trade emissions credits. For example, 1990 amendments to the Clean Air Act established *tradable emission credits* for the release of sulfur dioxide from such major sources as power plants. A facility was allowed to release only as much sulfur dioxide as it had credits for. But it could buy credits from a facility whose emissions were so low that it had unused credits. To avoid buying emission credits, many power plant operators decided to burn cleaner fuels or to install pollution control devices.

Some government regulations simply require businesses to tell the public how many pollutants they release into the environment. This type of regulation has caused some companies to find ways to reduce pollution so that consumers do not develop an unfavorable impression of them and perhaps refuse to purchase their products. The Emergency Planning and Community Right-to-Know Act, established in the United States in 1986, is an example of such a regulation.

Global efforts. Many types of environmental pollution have been difficult to control because no single person or nation owns the earth's global resources—that is, its oceans and atmosphere. To control pollution, the people of the world must work together.

Since the 1970's, representatives of many nations have met to discuss ways of limiting the pollution that affects air and water. These nations have created environmental treaties to help control such problems as acid rain, the thinning of the ozone layer, and the dumping of waste into oceans.

In 1992, representatives of 178 nations met in Rio de Janeiro, Brazil, for the United Nations (UN) Conference on Environment and Development. This meeting, known as the Earth Summit, was one of the most important global environmental conferences ever held. The UN members signed agreements on the prevention of global warming, the preservation of forests and endangered species, and other issues.

In 2001, 127 countries formed a treaty to ban or phase out the use of 12 *persistent organic pollutants* (POP's). These chemicals, which include the pesticide DDT, are carried across national boundaries by air and water, and they threaten the health of human beings and other animals. The treaty is expected to promote cooperation among scientists, industries, and governments to reduce the presence of POP's in the environment.

Scientific efforts. Increasing concern over environmental protection has caused scientists and engineers to look for technological solutions. Some research seeks ways to clean up or manage pollution. The goal of other research is to prevent pollution. Many industrial researchers are finding more economical ways to use fuels and other raw materials. As a result of their research, some European cities now use waste heat from power plants or trash incinerators to warm homes. New automobile engines burn gasoline much more cleanly and efficiently than older engines. Researchers have also developed automobiles that use such clean-burning fuels as *methanol* (a type of alcohol) and natural gas. In Brazil, some cars use another type of alcohol, called *ethanol,* as fuel. Scientists are also developing cars that can use hydrogen gas as fuel. Hydrogen creates almost no pollution when it is burned.

Scientists and engineers are also researching ways to generate electric power more cheaply from such renewable energy sources as the wind and the sun, causing little or no pollution. Large fields of windmills, known as *wind farms,* supply about 1 percent of California's electric power and more than 2 percent of Germany's. Devices called *photovoltaic cells* convert sunlight directly into electric power. Using such cells, a photovoltaic power plant in Sacramento, California, produces enough power for 1,000 homes.

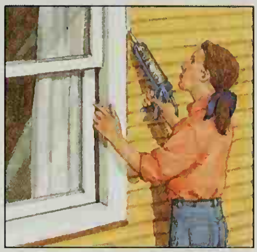
Business and industry. Many companies have discovered that it makes good business sense to pollute less. Some have found that reducing pollution gives them a better public image and saves money. Others have developed environmentally safe products or packaging to satisfy consumer demands. Still others develop pollution control systems because they believe that laws will eventually force them to do so anyway. Some companies limit pollution merely because the people running them choose to do so.

Environmental do's and don'ts

Reducing environmental pollution will require the efforts of people all over the world. The following illustrations show some of the ways individuals can help protect the environment.

WORLD BOOK illustrations by Yoshi Miyake

Buy sensibly, choosing products with minimal packaging to help reduce solid waste.



Insulate windows and use efficient appliances to conserve energy and reduce air pollution.

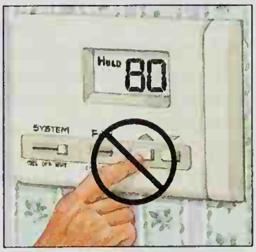
Ride a bike or use public transportation to avoid polluting the air with auto exhaust.

Turn off lights and appliances when not in use to save electric power.

Recycle as many different materials as possible instead of throwing them away.

Compost yard trimmings and food waste to keep garbage out of landfills and improve the soil.

Don't pour harmful chemicals down the drain. Take toxic materials to a drop-off center instead.



Don't overheat or overcool your home. Save energy by setting the thermostat appropriately.

In the past, the disposal of wastes was relatively inexpensive for most businesses. Today, legal waste disposal sites have become increasingly scarce in many areas. Regulation of certain types of waste has made their continued production extremely costly. As a result, many businesses have found ways to produce less waste or recycle the materials that they use. Manufacturers may use a minimum of packaging and choose packing materials that can be recycled. Lighter and less bulky packaging means distributors use less fuel transporting the products. In addition, the consumer throws out less packaging and creates less garbage.

Many businesses specialize in different types of pollution management. For example, some pollution management firms develop devices that remove harmful particulates from smokestack emissions. Particulates can be captured by filters, by traps that use static electricity, or by devices called *scrubbers* that wash out particulates with chemical sprays. The business of reducing and cleaning up pollution is expected to be one of the fastest growing industries of the future.

Other businesses assist companies in following government orders to clean up pollution. Some firms manage recycling or energy conservation programs. Still others help businesses develop less polluting processes.

Regardless of why or how industries begin to clean up pollution, it will be a slow, expensive process. Many businesses rely on the cheapest production methods available, even though such methods pollute. When the cost of cleaning up the pollution created by current production methods is added to manufacturing costs, however, methods that pollute less may prove more economical.

Some businesses have learned to work together to reduce their pollution. Waste materials from one industry can be used as a raw material by another industry. For example, a power plant in Kalundborg, Denmark, sells gypsum captured from burning fossil fuels to a nearby wallboard factory. It also sells ash to a cement manufacturer and steam to other nearby factories and homeowners. By sharing materials, industries can reduce pollution and waste while profiting from the exchange of resources. A field of study called *industrial ecology* explores these and similar opportunities related to reducing the impact on the environment from industrial and economic sources.

Agriculture. Scientists and farmers are developing ways to grow food that require less fertilizer and pesticides. Many farmers rotate their crops from year to year to reduce the need for chemical fertilizers. The rotation of corn, wheat, and other crops with legumes, such as alfalfa and soybeans, helps replace nitrogen lost from the soil. Crop rotation also helps control pests and plant diseases. Some farmers use compost and other fertilizers that are less harmful to the soil. Instead of spraying their crops with harmful pesticides, some farmers combat damaging insects by releasing other insects or bacteria that prey upon the pests. Scientists are also developing genetically engineered plants that are resistant to certain pests.

The rotation of crops and the use of natural pest enemies are called *natural pest control.* Combining a limited use of chemical pesticides with natural controls is

known as *integrated pest management* (IPM). Farmers using IPM apply chemical pesticides in smaller amounts and only when they will have the most effect.

Environmental organizations work to help control pollution by trying to influence lawmakers and to elect political leaders who care about the environment. Some groups raise money to buy land and protect it from development. Other groups study the effects of pollution on the environment and develop pollution prevention and management systems. Such groups use their findings to persuade government and industry to prevent or reduce pollution. Environmental organizations also publish magazines and other materials to persuade people to prevent pollution.

Political parties representing environmental concerns have formed in many industrial nations. These organizations, often known as *Green parties,* have had a growing influence on environmental policies. Countries with Green parties include Australia, Austria, Germany, Finland, France, New Zealand, Spain, and Sweden.

Individual efforts. One of the most important ways an individual can reduce pollution is by conserving energy. Conserving energy reduces the air pollution created by power plants. A reduced demand for oil and coal could also result in fewer oil spills and less destruction of coal-bearing lands. Driving less is one of the best ways to save energy and avoid polluting the air.

People can save electric power by buying more efficient light bulbs and home appliances. For example, compact fluorescent light bulbs use only 25 percent as much electric power as traditional incandescent bulbs. People can also conserve by using appliances less often, by turning off appliances and lights when not in use, and by setting home thermostats at or below 68 °F (20 °C) in winter and at or above 78 °F (26 °C) in summer. In addition, buildings with specially treated windows and good insulation need far less fuel or electric power to heat or cool than buildings without such materials.

People can also buy products that are safe for the environment. For example, households can help reduce water pollution by using fewer toxic cleaning products and by properly disposing of any toxic products they do use. If consumers refuse to purchase harmful products, manufacturers will stop making them.

Many cities and towns have recycling programs. Recycling saves energy and raw materials, and it prevents pollution. Many different waste products can be recycled. Commonly recycled wastes include metal cans, glass, paper, plastic containers, and old tires. Cans can be melted down and used to make new ones. Glass can be ground up and made into new containers or used as a substitute for sand in road pavement. Paper can be reprocessed into different paper products. Plastics can be melted down and re-formed into plastic lumber for such uses as fences, decks, and benches. They can also be reused to make carpeting. Old tires can be burned to produce energy. They can also be ground up and added to asphalt or some other adhesive to make roadbeds or such molded products as floor mats and playground equipment.

The most important way people can fight pollution is to learn as much as possible about how their actions affect the environment. Then they can make intelligent choices that will reduce damage to the planet.

History

Human beings have always caused some environmental pollution. Since prehistoric times, people have created waste. Like garbage today, this waste was either burned, tossed into waterways, buried, or dumped aboveground. However, the waste of early peoples was mostly food scraps and other substances that broke down easily by natural decay processes. Prehistoric populations were also much smaller and were spread out over large areas. As a result, pollution was less concentrated and caused few problems.

The growth of pollution started during ancient times when large numbers of people began living together in cities. As cities grew, pollution grew with them. Environmental problems became even more serious and widespread in the 1800's, during a period called the Industrial Revolution. This period was characterized by the development of factories and the overcrowding of cities with factory workers.

During the Industrial Revolution, coal powered most factories. Most city homes also relied on coal as a heating fuel. The burning of coal filled the air with smoke and soot. Poor sanitation facilities also allowed raw sewage to get into water supplies in some cities. The polluted water caused typhoid fever and other illnesses.

In the United States, air pollution problems became particularly serious in the early 1900's. By the 1930's, smoke and soot from steel mills, power plants, railroads, and heating plants filled the air over many Eastern and Midwestern cities. In some industrial cities, such as Pittsburgh, Pennsylvania, and St. Louis, Missouri, pollution frequently became so thick that drivers needed streetlights and headlights to see during the day.

Progress in controlling pollution has gained speed since the 1960's. Nearly all the railroads, industries, and homes of western Europe and the United States have switched from coal to cleaner-burning fuels, such as oil and natural gas. In many other places, pollution controls effectively limit the air pollution created by coal burning. Today, cities in many parts of the world also treat their water and process their sewage, thus greatly reducing the problems caused by harmful bacteria.

Important progress has been made in other areas of pollution management. Industrial waste, sewage, fertilizers, and other contaminants have polluted the Great Lakes since the mid-1800's. By the early 1970's, Lake Erie, Lake Ontario, and shallow regions of Lake Huron and Lake Michigan were so polluted that the waters had turned green and smelled foul, and huge fish kills were common. In 1972, Canada and the United States signed the Great Lakes Water Quality Agreement. Since then, local governments around the lakes have improved sewage treatment plants, controlled the runoff of chemical fertilizers from farms, and worked to reduce the use of phosphate detergents. They have also forced industries to reduce the pollutants they dump into the lakes. Today, the Great Lakes are much cleaner.

Current environmental issues

Current environmental issues include the need to weigh the benefits and risks of pollution controls, and the effects of population growth and of wastefulness in the industrialized world.

Paul Fusco, Magnum

The first Earth Day was celebrated in April 1970. Its purpose was to increase public awareness of environmental problems.

Weighing benefits and risks. Increased concern about the environment has caused people to protest many products and practices. Some of the disputed products and processes provide benefits to society. For example, people have argued against the use of disposable diapers because they take up space in landfills and decay slowly. But cloth diapers must be washed, and washing pollutes water and consumes energy. Nuclear power plants generate energy without creating air pollution. But such plants produce radioactive waste, which is difficult to dispose of. Business, environmental groups, and scientists work to determine which products, materials, and processes produce the most pollution. However, few choices are clear cut. It is often difficult to determine the relative risks and benefits to the environment of various products and practices.

When creating pollution laws, government officials must consider both the dangers of the pollutant and the possible financial effects of regulation. Regulations often require that an industry purchase expensive pollution control devices, make costly production changes, or discontinue manufacturing certain products. Such sudden expenses can cause some industries to go out of business, which creates unemployment. As a result, the effects of certain proposed pollution laws could harm people more than the pollutant would.

Effect of population growth. Despite progress in protecting the environment, the problem of pollution has become increasingly widespread and potentially more harmful. The main cause for the increase in pollution is that the earth's population grows larger every day. More people means more waste of every kind. As a result, one of the most important ways to begin controlling environmental pollution is to slow population growth. A reduction in population growth would slow the destruction and give people more time to develop effective pollution control systems.

Most of the world's population growth occurs in the poorest parts of the world, including certain nations in Africa, Asia, and Latin America. In these areas, people use what little resources they have just trying to stay alive. Governments in developing countries struggle to build modern industries and agricultural systems to provide a basic standard of living for their citizens. However, many developing countries use old technology that tends to pollute because they cannot afford modern, efficient machinery. Even if they could afford pollution controls, pollution in the developing world would continue to rise simply because these nations are industrializing. And more industry means more pollution.

Wastefulness in the industrialized world. Many people in Japan and in wealthy North American and European nations have become accustomed to comfortable lifestyles that consume large amounts of energy and raw materials and produce many wastes. A person living in an industrialized nation uses about 10 times the amount of fossil fuels and electric power and produces 2 to 3 times as much municipal waste as a person in a developing country. For a true reduction in pollution, people in the industrialized world would probably have to accept less convenience and luxury in their lives. Solving the problems of global environmental pollution will require the cooperation of governments and industry in all countries, rich and poor, as well as the efforts of individuals all over the world. Marian R. Chertow

Related articles. See **Air pollution** and **Water pollution** and their lists of *Related articles.* See also:

Acid rain
Animal (How human beings endanger animals)
Chlorofluorocarbon
City (Physical problems)
Conservation
Earth Day
Ecology
Energy supply (Environmental effects)
Environment
Environmental Defense Fund
Environmental impact statement
Environmental Protection Agency
Fallout
Green party
Hazardous wastes
Industry (Environmental pollution)
National park (Changes in the environment)
Nitrogen (Nitrogen and pollution)
Nuclear energy
Nuclear winter
Ocean (Marine pollution)
Ozone
Ozone hole
Pest control
Plastics (Plastics and the environment)
Radiation
Radon
Recycling
Thermal pollution
Waste disposal

Outline

I. **Types of pollution**
  A. Air pollution
  B. Water pollution
  C. Soil pollution
  D. Solid waste
  E. Hazardous waste
  F. Noise pollution

II. **Controlling pollution**
  A. Government action
  B. Scientific efforts
  C. Business and industry
  D. Agriculture
  E. Environmental organizations
  F. Individual efforts

III. **History**

IV. **Current environmental issues**
  A. Weighing benefits and risks
  B. Effect of population growth
  C. Wastefulness in the industrialized world

Questions

How can consumers encourage manufacturers to produce less polluting products?
What causes most air pollution?

What natural processes cleanse water systems?
How does the desire for convenience contribute to environmental pollution?
What are some ways governments work to control environmental pollution?
Why is solid waste difficult to eliminate?
How does population growth contribute to environmental pollution?
What are the hazards and benefits of ozone in the earth's atmosphere?
How can businesses help reduce pollution?
How do pesticides build up in the flesh of certain animals?

Additional resources

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Environmental Protection Agency (EPA) is an independent agency of the United States government. It was established in 1970 to protect the nation's environment from pollution. Creation of the Environmental Protection Agency brought under single management the functions of 15 federal programs that dealt with pollution.

The EPA establishes and enforces environmental protection standards and conducts research on the effects of pollution. It provides grants and technical assistance to states, cities, and other governmental units that seek to prevent pollution. The agency also helps the Office on Environmental Policy develop environmental protection policies and recommend them to the president.

The EPA administers provisions of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, also called "Superfund." The act provided $1.6 billion to clean up hazardous toxic waste sites and prosecute violators.

Early in 1983, the EPA came under heavy criticism from public interest groups and Congress for its handling of the Superfund program. Critics accused the agency of trying to destroy or delay progress in cleaning up the environment.

Congress began to investigate charges of wrongdoing. These accusations included manipulation of the Superfund program for political purposes, conflict of interest involving EPA officials with former ties to polluting firms, and lax enforcement against polluters. The agency's problems led to the resignation of EPA administrator Anne Burford in March 1983.

President Ronald Reagan named William D. Ruckelshaus, the first EPA chief, to succeed Burford. Ruckelshaus ended much of the criticism. A 1986 act reauthorized Superfund and provided an additional $9 billion. Lee Thornton

Enzyme, *EHN zym,* is a molecule that speeds up chemical reactions in all living things. Without enzymes, these reactions would occur too slowly or not at all, and no life would be possible.

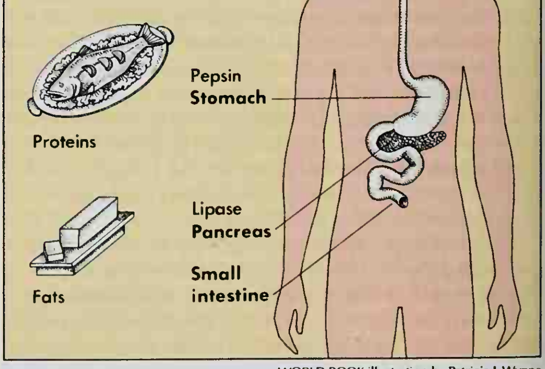
All living cells make enzymes, but enzymes are not alive. Enzyme molecules function by altering other molecules. Enzymes combine with the altered molecules to form a complex molecular structure in which chemical reactions take place. The enzyme, which remains unchanged, then separates from the product of the reaction. Enzymes thus serve as *catalysts* (see **Catalysis**). A single enzyme molecule can perform its entire function a million times a minute. The chemical reactions occur thousands or even millions of times faster with enzymes than without them. Most enzymes are proteins. A small number of RNA (ribonucleic acid) molecules also function as enzymes.

The human body has thousands of kinds of enzymes. Each kind does one specific job. Without enzymes, a person could not breathe, see, move, or digest food. Photosynthesis in plants also depends on enzymes.

Many enzymes break down complex substances into simpler ones. Others build complex compounds from simple ones. Most enzymes remain in the cells where they were formed, but some enzymes work elsewhere. For example, the pancreas secretes the enzyme *lipase,* which travels to the small intestine to break down fats.

The word *enzyme* comes from two Greek words meaning *in yeast.* Many scientists who studied enzymes in the 1800's studied reactions caused by yeast enzymes.

An American biochemist, James B. Sumner, was the first person to isolate a pure enzyme in the form of crystals. In 1926, he extracted the enzyme *urease* from beans



WORLD BOOK illustration by Patricia J. Wynne

Enzymes in the digestive system break down food for use in the body. Each enzyme performs a specific job. For example, *salivary amylase,* an enzyme produced by the salivary glands, splits carbohydrates into simpler chemicals. *Pepsin,* secreted by the walls of the stomach, acts on proteins. *Lipase* is secreted by the pancreas into the small intestine, where it breaks down fats.

and proved that enzymes are protein molecules. In 1969, scientists first chemically synthesized an enzyme, *ribonuclease,* from amino acids. This enzyme breaks down ribonucleic acid into molecules of other amino acids (see **RNA**). Today, scientists are trying to make new synthetic enzymes that carry out reactions not found in nature.

Structure. Enzymes are too tiny to be seen even with the most powerful light microscopes. However, scientists know through various research techniques that enzymes occur in a number of shapes and sizes. Although enzymes of different plants and animals have different protein structures, they function in similar ways. The structure of any particular enzyme enables it to cause chemical reactions in other molecules. Scientists sometimes change the structure of enzyme molecules to study how altered enzymes function or to make enzymes carry out different chemical reactions.

An enzyme's structure can easily be destroyed by heat, acids, or alkalis. Many deadly poisons act by damaging important enzymes. Hereditary diseases may occur in people born without certain enzymes. These diseases include such brain-damaging disorders as *galactosemia* and *phenylketonuria* (PKU). In many cases, tests can detect these enzyme deficiencies. Physicians can sometimes treat them with diet and drugs to prevent deformities, mental retardation, and even death.

Although most enzymes are proteins, some must be attached to certain nonprotein molecules in order to function. Many of these nonprotein molecules are metals, such as copper, iron, or magnesium. They occur within the body as *trace elements* (see **Trace elements**). Others are organic compounds called *coenzymes.* If a coenzyme is tightly attached to the protein part of the enzyme, the unit is called a *prosthetic group.* Neither the coenzyme nor the protein part of a prosthetic group can function alone.

Many coenzymes consist of vitamins, especially B vitamins. If a person's diet lacks adequate amounts of these vitamins, the enzymes cannot function properly, and various body disorders may develop. See **Vitamin** (How vitamins work).

Uses. Enzymes have many uses in addition to their natural functions in the body. Manufacturers use enzymes in making a wide variety of products. For example, some detergents contain enzymes that break down protein or fats that cause stains. Enzymes are also used in the manufacture of antibiotics, beer, bread, cheese, coffee, sugars, vinegar, vitamins, and many other products. Physicians use medicines containing enzymes to help clean wounds, dissolve blood clots, relieve certain forms of leukemia, and check allergic reactions to penicillin. Doctors also diagnose some diseases by measuring the amount of various enzymes in blood and other body fluids. Such diseases include anemia, cancer, leukemia, and heart and liver ailments.

In the future, enzymes may be widely used to change raw sewage into useful products. Enzymes also may be used to help get rid of spilled oil that harms lakes and oceans. The enzymes would turn the oil into food for sea plants. Frederick B. Rudolph

Related articles in *World Book* include:

Biochemistry	Digestive system	Food preservation
Cell	Fermentation	Pepsin

Eohippus. See **Horse** (Origins of the horse; diagram).

Eon. See **Earth** (Age of Earth).

Eoraptor, *EE oh RAP tuhr,* was one of the earliest dinosaurs. This meat-eating creature lived about 230 million years ago in what is now northwestern Argentina. Scientists believe *Eoraptor* may resemble the common ancestor of all dinosaurs.

Eoraptor had a slender body that grew about 3 feet (90 centimeters) long. Like many early dinosaurs, it ran upright on its hind legs, which were more than twice as long as its arms. *Eoraptor's* hands had five fingers. But it only used the three longest fingers on each hand to handle prey. These three fingers ended in large claws. The fourth and fifth fingers were probably too small to be of use.

Eoraptor probably ate a variety of small animals. The dinosaur could run quickly when pursuing prey. After catching its victim, *Eoraptor* used its large claws and teeth to kill the prey and tear it apart.

Eoraptor bones were first discovered in 1991. By 1993, scientists determined *Eoraptor* to be one of the most primitive dinosaurs. The animal lacked most of the specialized features in later meat-eating dinosaurs. For example, it did not have a sliding joint in its lower jaw to hold struggling prey. In addition, not all of its teeth were curved and *serrated* (saw-edged) like those of meat-eaters. *Eoraptor* only had such teeth in the back of its jaw. At the front of the jaw, its teeth were leaf-shaped like those of some plant-eating dinosaurs. *Eoraptor* belonged to a major group of dinosaurs called *saurischians,* or lizard-hipped dinosaurs. Saurischians had hip structures similar to those of modern lizards.

Hans-Dieter Sues

EPA. See **Environmental Protection Agency.**

Ephesians, *ih FEE zhuhnz,* **Epistle to the,** is the 10th book of the New Testament. The book is a letter that claims to be from the apostle Paul. However, many scholars believe this letter was written in Paul's name by one of his followers. If Paul wrote Ephesians, he did so while in prison, possibly in Rome, about A.D. 60. The first half of Ephesians describes the hope for the unification of all of God's creation in Christ and in the church. The second half urges Christians to live in a manner worthy of this calling.

According to Christian tradition, the letter was addressed to the church in Ephesus, located in present-day Turkey. However, the earliest copies of the letter do not mention Ephesus, or any other place. Some scholars believe the letter may have been sent to several churches with the address left blank. The reader of the letter would have then filled in the appropriate name at each destination. Terrance D. Callan

Ephesus, *EHF ih suhs,* was an ancient Greek city that stood about 35 miles (56 kilometers) south of modern-day Izmir, Turkey. It was founded by colonists from Athens in the early 1000's B.C. The city became famous for its Temple of Artemis, dedicated to the Greek goddess Artemis and considered one of the Seven Wonders of the Ancient World. The temple was built in the 500's B.C. over the remains of a structure from the 600's B.C. During the 500's B.C., the Lydians and then the Persians conquered Ephesus.

The city became a major trading and banking center under the Greeks in the 300's B.C. Later, Ephesus was the

capital of the Roman province of Asia. Saint Paul and Saint John helped establish a flourishing Christian church in Ephesus. The city became the leading Christian community of Asia. Ephesus later was looted by the Goths, Arabs, Turks, and finally the Mongols in A.D. 1403. The city was finally abandoned. Archaeologists uncovered its ruins in the late 1800's. Donald Kagan

See also **Seven Wonders of the Ancient World.**

Ephron, Nora (1941-), is an American journalist, essayist, and screenwriter. She first gained fame for her fresh and witty magazine columns about modern life. These writings were collected in her first three books—*Wallflower at the Orgy* (1970), *Crazy Salad: Some Things About Women* (1975), and *Scribble, Scribble: Notes on the Media* (1978). A fourth collection was published as *Nora Ephron Collected* (1991). Her 1983 novel *Heartburn,* the story of a failing marriage, was widely assumed to be based on her relationship with journalist Carl Bernstein, her second husband.

Ephron was born in New York City but raised in Beverly Hills, California, where her parents, Henry and Phoebe Ephron, were screenwriters. She was a reporter for the *New York Post* from 1963 to 1968 and wrote columns for *Esquire* magazine from 1972 to 1978 and for *New York* magazine in 1973 and 1974. Ephron was coauthor of scripts for such films as *Silkwood* (1983) and adapted *Heartburn* into a 1986 movie. Ephron also wrote the screenplay for *When Harry Met Sally* (1989). Ephron directed the films *This Is My Life* (1992) and *Sleepless in Seattle* (1993). Barbara M. Perkins

Epic is a long narrative poem. Almost all epics tell about the heroic deeds of divine beings and people in war or travel. In many epics, the hero is a *demigod,* born of one human parent and one divine parent. Some *cycles* (series) of epic poems developed around a hero or event. Many epics tell how a nation or people began. Some were created by several unknown authors over a long time. Other epics were written by one author.

Epics date back to prehistoric times. The earliest ones were sung by poets who accompanied themselves on a stringed instrument. These epics had no established text. The singers composed each line as they sang it, following the outline of a traditional tale. But every singer memorized certain descriptions, incidents, phrases, and scenes that could be used in making up verses. This method of composition is called *oral formulaic.*

In Western literature, epic poetry began with the *Iliad* and the *Odyssey.* Scholars believe these two works were composed by Homer, a blind Greek poet who may have lived during the 700's B.C. Both epics belonged to a cycle of poems based on the partly historical, partly mythical Trojan War. Homer's works served as models for later poets.

Greek and Roman literary critics prescribed rules for epics based on the style of Homer and his most important follower, the Roman poet Virgil. These rules stated that epics must begin *in medias res* (in the middle of things). That is, the story had to begin after much of the action had already taken place. Poets also had to write in a dignified style and begin with an "invocation" in which they asked a Muse for divine inspiration (see **Muses**).

During the Middle Ages, Greek and Roman epics and their rules were largely forgotten. Poets wrote epics in a more natural style. By the 1600's, the Greek and Roman models had been rediscovered. The English poet John Milton imitated Homer and Virgil in his epic *Paradise Lost* (1667). Beginning in the 1700's, the acceptance of realistic prose fiction, especially novels, helped lead to the decline of epic poetry. Paul B. Diehl

Related articles in *World Book* include:

Aeneid	Gilgamesh, Epic of	Ramayana
Ariosto, Ludovico	Iliad	Roland
Beowulf	Mahabharata	Spenser, Edmund
Cid, The	Nibelungenlied	Tasso, Torquato
Divine Comedy	Odyssey	

Epictetus, *EHP ihk TEE tuhs* (A.D. 50?-138?), was a Greek Stoic philosopher. He taught that we should not demand that events happen as we want. We should instead want them to happen as they do. A wise, divine Providence governs all things, so that what seem to be calamities are really parts of a divine plan that orders everything for the best. Epictetus thought that only foolish people are upset by events they cannot control. The true Stoic can face even death and all so-called misfortunes with perfect calm (see **Stoic philosophy**).

Epictetus was born in Asia Minor, and was a slave in his youth. He became free, and lived and taught in Rome until A.D. 89, when the Emperor Domitian expelled the philosophers. Epictetus spent the rest of his life teaching in Nicopolis, Greece. S. Marc Cohen

Epicurus, *EHP uh KYUR uhs* (342?-270 B.C.), was a Greek philosopher. His views on pleasure, freedom, and friendship had a great influence in the Greco-Roman world. The word *epicurean* comes from his name.

Epicurus believed that the human mind was disturbed by two main anxieties: fear of *deities* (gods and goddesses) and fear of death. He believed both fears were based on mistaken beliefs and could be overcome by the study of physics. According to Epicurus, physics proves that the movements of the heavens and meteorological phenomena are caused by the motions of atoms, not by deities. He said deities should not be feared because they are not concerned with human affairs.

Epicurus said that death should not be feared because good and evil lie in sensation, and death ends sensation. According to Epicurus, the soul is composed of atoms and these atoms disperse at death. Freed from anxieties over death, a person can live the good life by seeking moderate pleasures and avoiding pain. The modern term *epicurean* suggests excessive bodily pleasures, but Epicurus taught that pleasure can best be gained by living in accordance with prudence, moderation, courage, and justice, and by making friends.

Epicurus was born on the island of Samos. Except for three letters that summarize his teachings, his philosophy has been reconstructed from fragments of his many works and the poem *On the Nature of Things* by Lucretius (see **Lucretius**). Carl A. Huffman

Epidaurus, *EHP ih DAWR uhs,* is the site of several ancient Greek ruins, including a famous outdoor theater. This theater was built during the 200's B.C. and is the best preserved of all ancient Greek theaters. It seats more than 12,000 people and has excellent acoustics. In summer, many tourists go there to see ancient Greek plays performed in the modern Greek language. See **Drama** (picture: Ancient Greek theaters).

The ruins of an ancient temple honoring Asclepius, the Greek god of healing, are near the theater. This tem-

ple was built in the 300's B.C. Many sick people went to the temple in hope that Asclepius would cure them while they slept in a nearby guesthouse.

The ruins of Epidaurus lie near the eastern shore of the Peloponnesus, a peninsula of southern Greece. They are about 40 miles (64 kilometers) southwest of Athens.

Mortimer Chambers

Epidemic is an outbreak of disease that attacks many people at about the same time. An epidemic may last a few hours, a few weeks, or many years. When a disease exists permanently in a region, it is said to be *endemic.* A disease that spreads throughout the world is *pandemic.* The term *epidemic* traditionally has been used to describe outbreaks of infectious diseases, such as measles, cholera, and influenza. People now often use the term to describe increased incidences of such noninfectious diseases as lung cancer or heart disease. Scientists called *epidemiologists* study epidemics to understand their causes and to stop epidemics from spreading.

Methods of preventing epidemics can sometimes be found before the cause of the disease is known. For example, in the 1850's, English physician John Snow found that many Londoners with cholera obtained their water from a certain pump. He concluded that the water from the pump somehow caused the cholera. When officials closed down the pump, the incidence of cholera dropped. The bacterium that causes cholera, however, was not identified until the 1880's. Researchers studying AIDS in the early 1980's determined that the disease spread through sexual intercourse, through direct contact with infected blood, and from a pregnant woman to her fetus. Thus, even though HIV, the virus that causes AIDS, had not yet been identified, epidemiologists were able to recommend methods of AIDS prevention, such as the use of condoms during sexual intercourse.

Public health agencies are responsible for the control of epidemics. Immunizations can prevent epidemics of some infectious diseases, such as measles. Other epidemics are prevented by maintaining clean food and water supplies, or by controlling insects and other animals that spread disease. Informing people about the causes of epidemics and methods of prevention is crucial in the control of epidemics. Jane McCusker

See also **Plague** (History of plague).

Epidermis. See Skin.

Epiglottis. See Throat.

Epigram, *EHP uh gram,* is a short, witty poem or pointed saying. Its important features are compression, polish, balance, and clarity. Often in verse form, it is sometimes satirical. The English poet Samuel Taylor Coleridge wrote:

What is an epigram? A dwarfish whole,
Its body brevity, and wit its soul.

For the ancient Greeks, the epigram was a simple and brief inscription for a statue, a building, or a coin, or the epitaph for a tomb. But it changed from its original form and content. The Roman poet Martial developed the sharp and stinging epigram that we know today.

But epigrams are not always in verse. Popular sayings are really epigrams, as in "It never rains but it pours."

Marcus Klein

Epilepsy, *EHP uh* LEHP *see,* is a disorder of the brain characterized by sudden attacks, or seizures. This condition is said to exist when an individual has two or more seizures that do not result from infection, injury, a tumor, or other known cause. Doctors believe epileptic seizures occur when nerve cells in the brain suddenly release a large burst of electrical energy. Normally, brain cells produce some electrical energy, which flows through the nervous system and activates the muscles. The brain of an epileptic patient sometimes fails to control this release of energy.

Doctors classify epileptic seizures as either *generalized* or *partial.* Generalized seizures affect the whole brain at the same time. Two types of generalized seizures are *grand mal* and *petit mal.* Partial seizures begin in one area of the brain and sometimes spread to other areas. *Psychomotor epilepsy* is a type of partial seizure.

In a grand mal seizure, the most dramatic type of epileptic seizure, the patient suddenly loses consciousness. The person falls unless he or she is supported, and the muscles jerk. Most grand mal seizures last a few minutes, after which the patient goes into a deep sleep.

During a petit mal episode, the patient has a blank look and loses awareness of his or her surroundings for some seconds. The patient may appear confused but does not fall. Many of these episodes are not even noticed. Most petit mal seizures occur in children.

In a psychomotor seizure, the patient acts withdrawn and behaves strangely for a few minutes. The patient may roam around the room or tug at his or her clothes.

A person with epilepsy can have a seizure at any time of the day or night. Some patients have frequent attacks, but others rarely have them. Seizures seem to occur for no apparent reason, but fatigue and emotional stress can make them occur more often. In most cases, the first seizure occurs during childhood.

Scientists do not know what causes most cases of epilepsy. Some types are caused by defects in *genes,* the microscopic units of heredity. Epilepsy is not contagious. About 0.5 percent of all the people in the world have epilepsy.

Doctors treat epilepsy with drugs that either reduce the number of seizures or prevent them entirely. In certain cases, special diets have also been helpful. In cases where only one area of the brain triggers epileptic attacks, surgical removal of that area can lead to a complete cure. Most people with epilepsy can lead normal lives. The earlier treatment begins, the better the results.

Marianne Schuelein

See also **Electroencephalograph; Penfield, Wilder G.**

Additional resources

Landau, Elaine. *Epilepsy.* 21st Century Bks., 1994. Younger readers.

Lechtenberg, Richard. *Epilepsy and the Family.* Harvard Univ. Pr., 1999.

Epinephrine, *ehp uh NEHF rihn,* is a hormone secreted by the adrenal glands. It is also called *adrenalin.* Epinephrine helps the body adjust to sudden stress. When a person becomes angry or frightened, the adrenal glands release large amounts of epinephrine into the blood. The hormone causes changes in the body to make it more efficient for "fight or flight." For example, epinephrine increases the strength and rate of the heartbeat and raises the blood pressure. In addition, epinephrine speeds up the conversion of glycogen

into glucose, which provides energy to the muscles.

Epinephrine can be extracted from the adrenal glands of animals or it can be chemically synthesized. The drug stimulates the heart and relaxes muscles in the *bronchioles,* the small air passages in the lungs. Doctors use epinephrine to treat severe allergic reactions and to restore the heartbeat in patients who are suffering cardiac arrest. Epinephrine was once widely used to treat asthma attacks, but doctors now usually treat asthma with drugs that do not excite the heart.

Eugene M. Johnson, Jr.

Epiphany, *ih PIHF uh nee,* is a Christian festival. In Roman Catholic and Protestant churches, Epiphany commemorates the adoration of the infant Jesus by the Three Wise Men who had come from the East. In Eastern churches, it celebrates the baptism of Jesus. *Epiphany* comes from a Greek word that means *to appear* or *to show oneself.*

Most Christians celebrate Epiphany on January 6. Roman Catholics in the United States observe the festival on any Sunday from January 2 through January 8. During Epiphany in Western churches, Biblical texts are read in church that describe the various appearances of Jesus. In Eastern churches, the major observance is the blessing of baptismal water. Jill Raitt

See also **Twelfth Night.**

Epiphyte, *EHP uh fyt,* also called *air plant,* is any plant that grows on another plant but manufactures its own food. Most plants send roots into the soil and use them to obtain the moisture and chemicals they require for growth. But epiphytes take most of the moisture and raw materials they need for food directly from the air or

© John Stern, Animals Animals

Epiphytes grow on other plants, especially trees. Some epiphytes, such as Spanish moss, *above,* hang from tree branches.

from plant debris that has accumulated around their roots. Epiphytes have no true underground roots. Some of them receive moisture from the air through their leaves. Others have fleshy roots that dangle in the air to extract moisture from it.

Ephiphytes are different from parasitic plants. Parasitic plants fasten themselves to other plants and injure their hosts by feeding on their juices and tissues (see **Parasite**). But epiphytes may harm the plants they live on if they grow so abundantly as to deprive the host plants of light and air. Some take salts from the decaying bark of the trees upon which they live. Many epiphytes do not require living plants on which to live. They thrive attached to stones, buildings, or timbers.

Some epiphytes are found in temperate and cold climates, but most species grow in tropical forests. Temperate epiphytes include such small, inconspicuous plants as mosses and liverworts. Spanish moss is a well-known epiphyte of the Southern United States. The largest and most beautiful of the epiphytes live in the moist parts of the tropics. The most common epiphytes include orchids, aroids, bromeliads, and ferns. These plants may grow on any part of a tree but survive best on the trunk, in forks of limbs, and on large branches. Even the telephone wires of some warm moist regions support epiphytes. Thomas B. Croat

Related articles in *World Book* include:

Bromeliad	Lichen	Moss	Spanish moss
Fern	Liverwort	Orchid	

Episcopal Church, *ih PIHS kuh puhl,* is a Christian denomination in the United States. The denomination was known as the Protestant Episcopal Church until 1967, when a general convention adopted the Episcopal Church as an alternate name. The Episcopal Church developed from the Church of England and is part of the Anglican Communion, an international organization of 28 self-governing churches. English settlers brought the Episcopal Church to the Virginia Colony in 1607. It became a separate group when it adopted a constitution and body of *canons* (religious laws) and a revision of the Book of Common Prayer in Philadelphia in 1789. For information on its doctrine, see **Anglicans.**

The Episcopal Church has over 100 dioceses and about 12,000 clergy in the United States. It also supports missionary activities in many parts of the world. A General Convention of bishops, priests, and laity that meets every three years governs the church. A presiding bishop heads the convention's House of Bishops and the Executive Council, which puts the convention's decisions into practice. Regional dioceses and local parishes have much *autonomy* (self-government). The church has about 2,500,000 members. Headquarters are in New York City. Critically reviewed by the Episcopal Church

Episcopalians. See **Anglicans; Episcopal Church.**

Epistle, *ih PIHS uhl,* can refer to any letter written to an individual or a group. However, the word usually describes a letter that is formal and serious in tone, impersonal, and instructive.

The term *epistle* is particularly associated with 21 books of the New Testament. The Roman orator and statesman Cicero wrote epistles on subjects ranging from politics to philosophy. More than 800 of his letters have survived and remain a major source for the study of Roman history and thought. A number of poets have used the epistle form for their verses. The Roman poet Horace composed many verse epistles between 20 and 8 B.C. The English poet Alexander Pope imitated Horace in such satirical poems as "An Epistle to Dr. Arbuthnot" (1735) and "An Epistle to Augustus" (1737). Pope's verse epistles gained a new popularity for the form during the 1700's. Epistolary novels such as Samuel Richardson's *Pamela* (1740) and Alice Walker's *The Color Purple* (1982) take the form of letters exchanged between fictional characters. William H. Epstein

For a list of articles on New Testament epistles, see the *Related articles* in **Bible.** See also **Pope, Alexander.**

Epithelioma, *EHP uh THEE lee OH muh,* is any tumor of the *epithelium,* the tissue that lines the body cavities and covers the body surface and the internal organs. These tumors may be either benign or malignant. However, most doctors use the term *epithelioma* to denote *basal cell carcinoma,* a common skin cancer. Such a cancer often begins as a small sore that will not heal. But sometimes it will seem to heal over, and then reappear. These tumors may be caused by prolonged exposure to the sun, X rays, or by materials containing tars or arsenic. Unlike most cancers, malignant epitheliomas usually do not spread to other parts of the body. They can be cured by surgery. Martin D. Abeloff

Epithelium, *EHP uh THEE lee uhm,* is one of the major kinds of tissue formed in the bodies of human beings and some animals. It covers the body surface and lines the channels of the body that have openings to the outside. For example, the respiratory tract, alimentary tract, and the urinary tract are lined with epithelium.

Three types of cells make up the epithelium. They are the *squamous, cuboidal,* and *columnar* cells. These cells are differentiated by their shape. The squamous cells are thin and scalelike. They have irregular edges. These cells make up the tissue that covers the body surface and lines the mouth and esophagus. Cuboidal cells look like tiny cubes. They are almost as tall as they are broad. These cells line some of the body cavities and are found in many of the glands. Columnar cells resemble columns. They are much taller than they are broad. Tissue made up of these cells lines the stomach and intestines, and the innermost layer of the *epidermis* (skin). A form of columnar epithelium equipped with cilia lines the respiratory passages. Paul R. Bergstresser

See also **Epithelioma**.

Epsom salt, *EHP suhm,* is a white powder that in the past was commonly used as a laxative. It was also mixed with water to make a solution for soaking *inflamed* (red and swollen) body parts. Epsom salt is now rarely used.

As a laxative, Epsom salt prevents the *bowels* (intestines) from absorbing water. The water creates bulk, causing the bowels to discharge their contents. Epsom salt should not be taken frequently because it interferes with the absorption of food materials. It should never be taken when there is abdominal pain.

Epsom salt is a powder form of the chemical magnesium sulfate. It is named for the springs in Epsom, England, where it was first obtained. Brian V. Reed

Epstein, *EHP styn,* **Sir Jacob** (1880-1959), was an American-born sculptor who spent most of his life in London and became a major figure in British sculpture. Epstein worked mainly in bronze and stone. Most of his sculpture has recognizable subject matter that is modified by his own individual style. At first, Epstein's sculpture aroused hostile criticism. But later in his life, his work became more popular.

Much of Epstein's early work, such as *The Rock Drill* (1913), was influenced by primitive art. Many of his human figures are long and thin with coarse surfaces and have a tormented appearance. Many of his public commissions are devoted to religious themes. Epstein also executed many portraits that are noted for their emotional emphasis and rough surfaces. Examples include *Albert Einstein* (1933) and *Lord Russell* (1953).

Epstein was born in New York City and moved to London in 1905. He became a British subject in 1910, and Queen Elizabeth II knighted him in 1954. Joseph F. Lamb

Epstein-Barr virus, *EHP styn BAHR,* often called EBV, is a type of herpesvirus that causes infectious mononucleosis. EBV infects white blood cells called *B lymphocytes* and reproduces in mucous membranes, especially in the throat. Most people will become infected with EBV during their lives. Infection with EBV before age 15 usually causes no symptoms, or a mild flulike illness. Infection during adolescence or early adulthood usually causes infectious mononucleosis. Like other herpesviruses, EBV can persist in the body for years, alive but dormant, and later become activated.

The virus was first isolated by British scientists M. Anthony Epstein, Yvonne M. Barr, and Bert G. Achong in 1964. Scientists have linked the virus to a type of cancer called *Burkitt's lymphoma,* and to cancers of the nose and throat among certain populations. Nelson M. Gantz

See also **Herpesvirus; Mononucleosis.**

Equal Employment Opportunity Commission (EEOC) is a United States government agency. It enforces laws that prohibit job discrimination because of race, color, religion, sex, national origin, age, or disability. These laws are the Equal Pay Act of 1963; Title VII of the Civil Rights Act of 1964; the Age Discrimination in Employment Act of 1967; and Section 501 of the Rehabilitation Act of 1973. The commission investigates complaints of job discrimination by public and private employers, labor unions, and employment agencies. If an investigation shows reasonable cause to believe that discrimination has occurred, the EEOC works to help negotiate a settlement. If negotiations fail, the EEOC may sue in federal court.

The EEOC was set up under the Civil Rights Act of 1964 and began operating in 1965. The Equal Employment Opportunity Act of 1972 broadened the EEOC's powers.

Critically reviewed by the Equal Employment Opportunity Commission

See also **Civil Rights Act of 1964.**

Equal Rights Amendment is a proposed amendment to the United States Constitution. It states that men and women must be treated equally by law. The amendment reads: "Equality of rights under the law shall not be denied or abridged by the United States or any state on account of sex."

The amendment, often called the *ERA,* was first introduced in Congress in 1923 through the efforts of the National Woman's Party. This party works for total equality for women. After years of nationwide controversy, Congress passed the ERA in 1972. To become law, a constitutional amendment must also be *ratified* (approved) by the legislatures of three-fourths of the states.

Congress required that the ERA, like most amendments passed by Congress since the early 1900's, be ratified within seven years. Supporters of the amendment had until March 22, 1979, to obtain ratification by 38 states. But in 1978, Congress voted to extend that deadline until June 30, 1982. By the 1982 deadline, only 35 of the necessary 38 states had ratified the amendment. Since 1983, the ERA has been reintroduced in Congress a number of times, but it has not been passed.

Critics of the amendment say that the Constitution already guarantees equal rights to women. They also claim the ERA would abolish the right of a wife to

be supported by her husband. Supporters of the ERA argue that, despite the guarantees of the Constitution, women do not always receive equal treatment. They also claim that the amendment would not affect personal relationships within marriage.

The ERA would make several state and local laws unconstitutional. For example, it would outlaw restrictions on the types of jobs women may hold and the number of hours a week they may work. The amendment also would ban all laws that give one sex different rights than the other. June Sochen

See also **Women's movements** (Legal gains); **Paul, Alice; Schlafly, Phyllis S.; Sex discrimination.**

Additional resources

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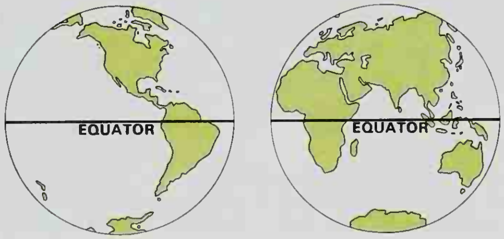
Mansbridge, Jane J. *Why We Lost the ERA.* Univ. of Chicago Pr., 1986.

Mathews, Donald G., and De Hart, J. S. *Sex, Gender, and the Politics of E.R.A.* 1990. Reprint. Oxford, 1992.

Equator is the great circle of the earth that lies halfway between the North and South poles. This imaginary line divides the earth into two equal parts called the Northern Hemisphere and the Southern Hemisphere. It is the starting point for the degrees of latitude that measure distances north and south from the equator to the poles (see **Latitude**). The latitude of the equator is zero. On a globe, the equator is also a line on which equal distances are marked to show degrees of longitude, which measures east and west distances (see **Longitude**). The circumference of the earth at the equator is 24,901.55 miles (40,075.16 kilometers). Each degree of longitude at the equator equals 69.17 miles (111.32 kilometers).

The location of the equator can be determined by observing the elevation of the North Star or the sun above the horizon. Allowing for slight corrections, the angle of elevation of the North Star at any given place equals the latitude of that place. Thus, at the equator, the North Star is barely visible above the horizon and has an elevation of nearly zero degrees.



WORLD BOOK maps

The equator circles the earth.

The equatorial climate. The climate along the equator varies according to altitude and the distance from the sea. In most equatorial lowlands, heavy rains and average temperatures are uniform all year. But the east coast of Africa has only light rain and a long dry season. Quito, Ecuador, which lies almost exactly on the equator, has an elevation of 9,350 feet (2,850 meters). It has a uniform temperature that is about 25 Fahrenheit degrees (14 Celsius degrees) cooler than nearby lowlands.

The celestial equator is an imaginary circle that goes around the sphere in which the earth and heavenly bodies lie. It helps locate stars and planets. See **Astronomy** (Locating objects in space).

The magnetic equator is the line on which all points are equally distant from the north and south magnetic poles. See **Magnetic equator.** Stephen S. Birdsall

Equatorial Guinea, *GIHN ee,* is a small country in western Africa. It consists of a territory on the west coast of the continent, plus five offshore islands. Most of the nation's people live in the territory, Río Muni, which lies between Cameroon and Gabon. The largest island, Bioko (formerly Fernando Po), is in the Gulf of Guinea, about 100 miles (160 kilometers) northwest of Río Muni. The other islands—Corisco, Elobey Chico, Elobey Grande, and Annobon—are southwest of Río Muni. Malabo is the nation's capital. Bata is the largest city of Equatorial Guinea.

Equatorial Guinea became independent in 1968. It had been ruled by Spain since the mid-1800's.

Government. A president heads the government of Equatorial Guinea. The people elect the president to a seven-year term. An 80-member House of Representatives makes the country's laws. Its members are elected by the people to five-year terms.

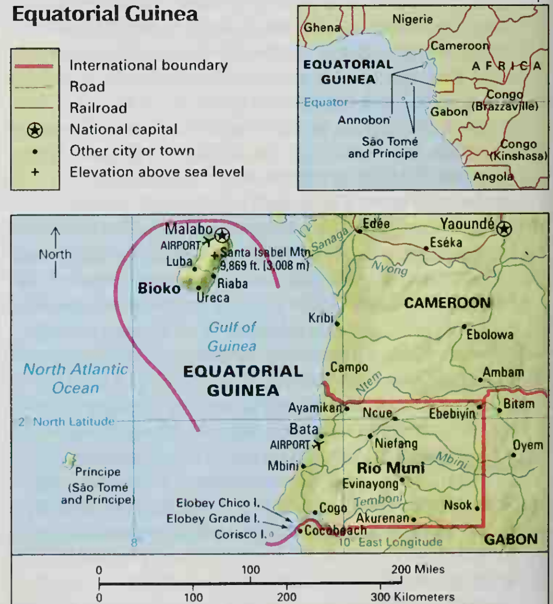
People. About 80 percent of Equatorial Guinea's people live in Río Muni. Most of the people in Río Muni are members of the Fang, a black African ethnic group. The Fang are closely related to the people of neighboring Cameroon and Gabon. Most of the people of Bioko are also black Africans. They belong to the Fernandino or Bubi ethnic groups.

Most of the people who live in Equatorial Guinea's rural areas are farmers. Others fish or work in lumber camps for a living. Many of the urban people work in small industries or in import-export activities.

Spanish is the official language of Equatorial Guinea. It is used in the government and in the commerce and schools of the country. But the most widely used lan-

WORLD BOOK maps

Equatorial Guinea



Facts in brief

Capital: Malabo.
Official language: Spanish.
Official name: República de Guinea Ecuatorial (Republic of Equatorial Guinea).
Total land area: 10,831 sq. mi. (28,051 km^2).
Elevation: *Highest*—Santa Isabel Mountain, 9,869 ft. (3,008 m). *Lowest*—sea level along the coast.
Population: *Estimated 2002 population*—475,000; density, 44 persons per sq. mi. (17 per km^2); distribution, 63 percent rural, 37 percent urban. *1983 census*—300,000.
Chief products: Bananas, cacao, cassava, coffee, sweet potatoes, timber.
Flag: The flag has green, white, and red horizontal stripes, and a blue triangle at the staff. The national coat of arms is on the white stripe. The flag was used from 1969 to 1978 and was readopted in 1979. See **Flag** (picture: Flags of Africa).
National anthem: "Caminemos pisando la senda de nuestra inmensa felicidad" ("Let's walk down the path of our immense happiness").
Money: *Basic unit*—franc. One hundred centimes equal one franc.

guage is Fang. Roman Catholicism is the most widespread religion in Equatorial Guinea. About three-fourths of the people are Catholics. Most of the others practice traditional African religions.

The law requires children in Equatorial Guinea to go to school until the age of 12. However, many do not attend because of a shortage of teachers. Bata and Malabo have teacher-training schools. There are no colleges or universities in Equatorial Guinea.

One of the nation's major problems is its limited health service. Equatorial Guinea has only a few physicians, and the lack of health care has caused the spread of malaria, measles, and other diseases.

Land and climate. Dense tropical rain forests cover much of Equatorial Guinea, but plains line the coasts of Río Muni and Bioko. Crops of bananas, coffee beans, and *cacao* (beans from which cocoa is made) thrive in the rich volcanic soil of Bioko. The soil of Río Muni is poor for agriculture but coffee is grown in the territory, and wood from Río Muni's forests is used for lumber.

Equatorial Guinea has a hot, humid climate. Temperatures average higher than 80 °F (27 °C). The annual rainfall varies from 76 inches (193 centimeters) in Malabo to 430 inches (1,090 centimeters) in Ureca.

Economy of Equatorial Guinea is based chiefly on agriculture. The main food crops include bananas, cassava, and sweet potatoes. The nation produces much cacao for export. About 90 percent of the cacao comes from Bioko. Fishing is an important activity, especially on the offshore islands.

Equatorial Guinea has many trees, and forestry is important to the economy. The *okoumé tree,* the country's most important tree for timber, is used to make plywood. Equatorial Guinea has some food-processing plants, but little manufacturing. Oil production is a growing industry.

The chief ports include Bata, Luba, Malabo, and Mbini. The country has two international airports. Equatorial Guinea has two radio stations and one television station, all of which are operated by the government. Less than 1 percent of the people own a TV set.

History. Pygmies were probably the earliest people who lived in what is now Río Muni. They inhabited the area before the 1200's. Various ethnic groups, including the Bubi, Benga, and Fang, then occupied the Río Muni area until the 1700's. Bubi from the mainland settled on Bioko during the 1200's. They were the first people to live on the island. The Portuguese landed on Annobon in 1471. They later claimed Annobon, Bioko, and part of the mainland coast. Spain gained control of these territories in the mid-1800's and made them a colony in 1959.

Equatorial Guinea became an independent nation on Oct. 12, 1968. Later that year, Francisco Macias Nguema took control of the government as president and dictator. In 1979, a group of army officers led by Lieutenant Colonel Teodoro Obiang Nguema Mbasogo overthrew Macias Nguema and established a military government with Obiang Nguema as president. In 1989, Obiang Nguema was elected president in an election in which only his party, the Democratic Party for Equatorial Guinea, was allowed. In 1991, Equatorial Guinea adopted a new constitution that provided for a multiparty system. In 1996, Obiang Nguema was reelected president in a multiparty election. Immanuel Wallerstein

See also **Malabo**.

Equatorial Islands. See **Line Islands**.

Equestrian order, *ih KWEHS tree uhn,* was a class of prominent citizens in ancient Rome. Most of the order's members were aristocrats. Originally, they served in the cavalry of the Roman legions. The members of the order were called *equites* (pronounced *EHK wuh teez*), a Latin word meaning *horsemen* or *knights.* The order's military significance declined as cavalry more effective than the equites was recruited from among Rome's allies. However, the equites retained their political, social, and economic importance.

During the 100's B.C., the equestrian order expanded and large numbers of nonaristocrats were admitted to it. Over time, the power of the order increased at the expense of the power of the Roman Senate. The equites, for example, gained control of important courts that could try senators. They also engaged in business activities from which senators were excluded.

Although the equites sometimes opposed the Senate, they belonged to the same social and economic level of Roman society as the senators. They intermarried with senatorial families and shared the interests and attitudes of most senators. During the Roman Empire, equites were appointed to high civil and military offices, including viceroy of Egypt and commander of the Praetorian Guard. D. Brendan Nagle

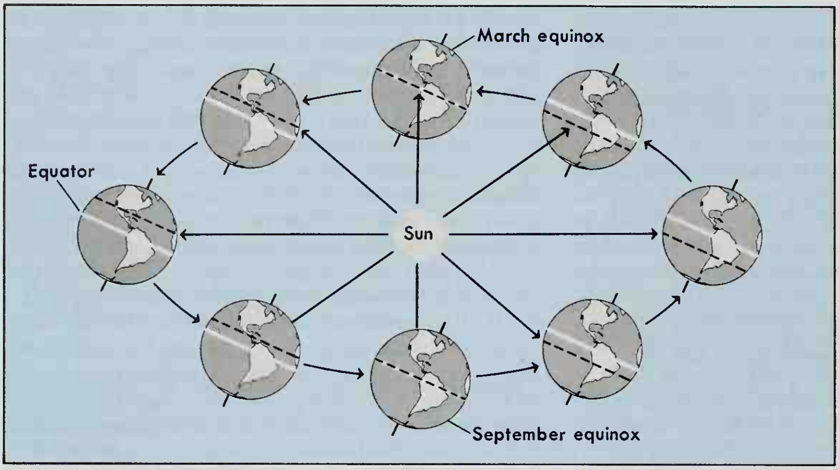
Equestrian sports. See **Horse** (Horse shows and sports).

Equilibrium, in physics. See **Gravity, Center of; Lever; Statics.**

Equilibrium, *EE kwuh LIHB ree uhm,* **Chemical,** is a state of balance between a pair of *forward* and *reverse* chemical reactions. A double arrow in a chemical equation such as the one below indicates equilibrium. At equilibrium, the rate of the forward reaction (left to right in the equation) is equal to the rate of the reverse reaction (right to left).

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

In the forward reaction illustrated by the above equation, nitrogen, N_2, is combining with hydrogen, H_2, to



The equinoxes are the two days of the year when the sun is directly above the equator. As the earth moves in its orbit around the sun, the position of the sun changes in relation to the equator, as shown at the left by the dotted lines. The sun appears north of the equator between the March equinox and the September equinox. It is south of the equator between the September equinox and the next March equinox.

WORLD BOOK diagram

form ammonia, NH_3. In the reverse reaction illustrated by the equation, ammonia is breaking up into nitrogen and hydrogen. At equilibrium, the concentrations of the various substances do not change. In general, temperature and pressure affect the concentrations of chemicals in an equilibrium mixture. Peter A. Rock

Equinox, *EE kwuh nahks,* is either of the two days of the year when the sun is directly above the earth's equator. At these times, the days and nights are of nearly equal length everywhere on the earth. The term *equinox* comes from a Latin word meaning *equal night.*

The equinoxes occur on March 19, 20, or 21 and on September 22 or 23. In the Northern Hemisphere, the March equinox marks the start of spring and is often called the *vernal equinox.* The position of the vernal equinox is called the *first point of Aries.* The word *vernal* means *of spring.* The September equinox marks the beginning of autumn and is called the *autumnal equinox.* The seasons are reversed in the Southern Hemisphere.

The time interval from the March equinox to the September equinox is longer than that between the September equinox and the next March equinox. This time difference results from the earth's *elliptical* (oval-shaped) orbit around the sun. The earth moves faster in its orbit when it is closer to the sun. The distance between the earth and the sun is shortest in January. Therefore, the earth completes the semicircle from the September equinox to the March equinox faster than it does the opposite semicircle.

Astronomers also use the term *equinox* for either of two imaginary points where the sun's apparent path among the stars crosses the *celestial equator.* The celestial equator is an imaginary line through the sky directly over the equator.

The positions of the two equinoctial points do not remain the same from year to year. They shift westward extremely slowly—about 1 degree every 70 years. This gradual movement of the points, called the *precession of the equinoxes,* is caused by a slight change in the direction of the earth's axis of rotation. The change results mainly from the gravitational pull of the moon and the sun on the earth's equatorial bulge. Lee J. Rickard

See also Solstice.

Equity, *EHK wuh tee,* in law, usually refers to a set of rules that were developed from broad principles of reason and justice. The rules became important in England during the Middle Ages. They were used instead of English common law in cases where basing a judgment on common law would have produced an unfair result. Equity was later adopted in the United States, Canada, and many other countries. The term *equity* comes from a Latin word meaning *even* or *fair.*

Equity allows the law to adjust to the unique circumstances of a case. For example, a person may borrow money and give the lender a *mortgage* (claim on the borrower's property) as security. The borrower promises to repay the loan by a specified date. The borrower also agrees that if the loan is not repaid by that date, he or she will forfeit the mortgaged property. Normally, a court would enforce the agreement. Sometimes, however, the property has a value that greatly exceeds that of the loan. In such cases, the court may use principles of equity to order the property sold. If the court orders the property sold, the debt and the court costs are paid from the proceeds and the rest of the money is returned to the borrower. This result is fairer than a forfeiture of the total value of the property by the borrower.

Equity came into use in England because the English courts had applied common law so strictly that injustices were created in many cases. In some cases, a party to the lawsuit asked the king to step in and provide relief by judging the case according to broad principles of justice rather than to the strict letter of the law. A minister of the king called the *chancellor* reviewed petitions to hear such cases. The chancellor eventually became head of a court of equity called the *court of chancery.*

The court of chancery and other courts of equity differed from England's courts of common law. The courts of common law used juries, but the courts of equity did not. The two kinds of courts also had different powers. Courts of common law could only award compensation for damages after an injury was done. Courts of equity could also issue *injunctions,* which required one or more persons to do, or not to do, something.

In England, the court of chancery was once the highest court next to the House of Lords. But in 1873, a law was passed that merged the court of chancery with the

common law courts to form the High Court of Justice.

Many U.S. states once had courts of equity that were separate from the states' *courts of law.* But in most of these states today, the two kinds of courts have been merged into one court called a court of law. In some states, an unmerged court of equity is known as a *court of chancery,* and its presiding judge is called a *chancellor.* Federal equity courts and federal law courts in the United States have also been merged.

The term *equity* has special meanings in bookkeeping, taxation, and real estate law. For information on these types of equity, see **Bookkeeping; Mortgage;** and **Taxation** (Principles of taxation). Linda Henry Elrod

See also **Common law; Injunction.**

ERA. See **Equal Rights Amendment.**

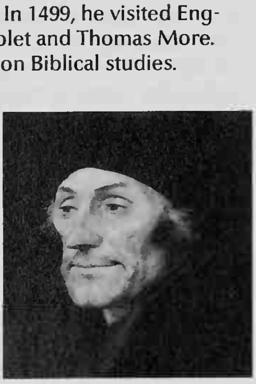
Eraser is a device for removing marks from paper or some other surface. Pencil erasers remove pencil marks by rubbing. Most pencil erasers are made of soft rubber that crumbles gradually when used. A compound called *gum eraser* crumbles more easily and is used on surfaces easily damaged by rubbing. Ink erasers contain powdered pumice or a similar material that removes some of the paper, exposing a clean surface. Some inks can be removed with erasing fluids. Erasing fluids may consist of a bleach called *hypochlorite* and an acid applied in succession, and then removed by blotting.

Chalkboard erasers remove chalk marks by wiping. Most such erasers are made of strips of felt attached to a stiff backing. Erasers for *dry-erase boards* are made of nylon or other synthetic fibers. Dry-erase boards are nonporous, and special markers are used to write or draw on them. The marks become a dust that is attracted to the eraser. Critically reviewed by Sanford

Erasmus, *ih RAZ muhs,* **Desiderius,** *DEHZ ih DEER ee uhs* (1466?-1536), was a Dutch priest and scholar who sought to reform the church. At first, he supported the German theologian Martin Luther and other leaders of the Reformation, the religious movement that gave birth to Protestantism. These reformers opposed the corruption and dogmatism they and Erasmus saw in the church. However, he believed in the unity of Christianity and so refused to endorse the establishment of a separate church. Erasmus failed in his efforts to create a moderate, humane middle ground in the fierce conflict between Catholics and Protestants.

Erasmus was born in Rotterdam, the Netherlands. He was ordained a priest in 1492. In 1499, he visited England and met scholars John Colet and Thomas More. They persuaded him to focus on Biblical studies.

In his *Handbook of a Christian Soldier* (1503), Erasmus presented what he called the *philosophy of Christ.* This philosophy stressed piety, morality, and dedication to truth. In his satire *The Praise of Folly* (1511), he criticized the clergy for neglecting these values and instead emphasizing ceremonies and the letter of the law. Erasmus's 1516 edition of the New Testament in Greek made the original text available for the first time. Jill Raitt



Varnished tempera portrait on linden wood (1532) by Hans Holbein the Younger; Kunstmuseum, Basel, Switzerland

Desiderius Erasmus

Eratosthenes, *ehr uh TAHS thuh neez* (276?-195? B.C.), was a Greek mathematician. He found a way of measuring the distance around the earth without leaving northern Africa, where he lived. Eratosthenes also developed the *Sieve of Eratosthenes*—a method of identifying prime numbers (see **Sieve of Eratosthenes**).

Eratosthenes was born in Cyrene, a Greek town in northern Africa. Like other Greek scientists of his time, he knew that the earth was round. He observed that shadows at noon grew shorter as he got closer to the equator. Eratosthenes also knew that at noon on the day of the summer solstice in Alexandria, Egypt, a vertical post casts a shadow. But at noon in Syene, a town to the south, a vertical post casts no shadow.

Eratosthenes based his calculation on geometry. He measured the angle formed by the post and an imaginary line from the end of the shadow to the top of the post. By treating the sun's rays as parallel, he could assume that the measured angle equaled the angle formed at the earth's center by imaginary lines from the two towns. He then calculated the earth's circumference by measuring the distance between Alexandria and Syene and multiplying it by the number of times the angle at the earth's center goes into 360°. His measurement of the earth's polar circumference was between 28,000 and 29,000 miles (45,000 and 47,000 kilometers). The actual value is 24,860 miles (40,008 kilometers).

Judith V. Grabiner

Erbium, *UR bee uhm* (chemical symbol, Er), is one of the rare earth metals. Its atomic number is 68. It has an atomic weight of 167.26. It has six known isotopes. The Swedish scientist Carl Mosander discovered it in 1843. Erbium is found associated with the heavier rare earths, such as europium and gadolinium, chiefly in the yttrium minerals. It is best separated from the other rare earths by ion-exchange processes or solvent extraction. Erbium of high purity is available commercially. The metal has a grayish-silver color. It melts at 1529 °C and boils at 2868 °C. It has a density of 9.045 grams per cubic centimeter at 25 °C. Erbium forms Er_2O_3, a rose-pink oxide used to make pink glass. See also **Element, Chemical** (table); **Rare earth; Yttrium.** Larry C. Thompson

Erechtheum. See **Acropolis.**

Ergonomics, *UR guh NAHM ihks,* is the science of designing machines, objects, and environments to match the physical and psychological needs of human beings. One example of ergonomic design is a type of computer keyboard that features special shaping and support to prevent strain on hands and wrists. Such strain can lead to muscle or nerve damage when people spend long hours typing. The most widespread use of ergonomics is in workplaces. Many ergonomic products are also used in homes. Ergonomics is also known by the terms *human factors engineering* and *human engineering.*

The science of ergonomics developed from studies conducted during the the early 1900's. At that time, engineers discovered that the efficiency of a machine often depends on the mood and comfort of the person operating it. At the same time, sociologists, psychologists, and other social scientists studied human behavior to learn how psychological factors affect production. Today, scientists and designers use ergonomic principles

to create workplaces and equipment that are safe, comfortable, and satisfying for people. Thomas T. Liao

See also **Repetitive strain injury.**

Ergot, *UR guht,* is a parasitic fungus that attacks wheat, barley, rye, and many wild and cultivated grasses. It most commonly infects rye. Ergot attacks the grain of the plant. Long purple structures of the fungus called *sclerotia* form in place of the seeds of the host plant. In the spring these sclerotia grow and produce stalks and spores. The spores ripen and are scattered by the wind to infect new plants. Ergot infection can be reduced or prevented by rotating crops, using clean seed, and cutting grasses that may harbor the disease.

Ergot also causes a disease called *ergotism* in human beings and cattle. This disease was common among people who ate bread made from rye grain that contained ergot sclerotia. The symptoms were often gangrene and convulsions. The disease has now practically disappeared because of improved methods of cleaning grain.

Ergot sclerotia are the source of a number of drugs, such as *ergonovine, ergotoxine,* and *ergotamine.* The most common uses of these drugs are to ease migraine headaches and to prevent hemorrhage after childbirth.

Joe F. Ammirati

Scientific classification. Ergot belongs to the family Clavicipitaceae in the kingdom Fungi. It is *Claviceps purpurea.*

Eric the Red (A.D. 950?-1000?) was a Viking explorer who colonized Greenland. His name was Eric Thorvaldson, but he was called Eric the Red because of his red hair. His name is also spelled *Erik* or *Eirik.*

Eric was born in Jaeren, in southern Norway. When he was about 10 years old, his father was outlawed for manslaughter. The father and son then moved to Iceland. After his father died, Eric became involved in several quarrels and killings and was exiled from Iceland for three years. During his exile, Eric explored the waters west of Iceland for land that Gunnbjorn Ulfsson, a Norwegian, had sighted about A.D. 900. Eric reached Greenland and spent the rest of his exile there. He then returned to Iceland. Eric named the new land Greenland to attract people to it.

About 985, Eric sailed for Greenland with 25 ships of colonists, but only 14 of the vessels completed the voyage. Two settlements, with a total of about 450 people, were established—the Eastern Settlement on the southwest coast and the Western Settlement about 300 miles (480 kilometers) north. Eric lived in the Eastern Settlement at Brattahlid, near what is now Julianehåb. He was the principal leader of both communities. The settlers farmed the land; raised cattle, hogs, and sheep; and hunted bears, caribou, walruses, and other animals.

Eric planned to lead an expedition west from Greenland to find more land. But he refused to make the journey after falling from his horse on the way to his ship. Eric feared the accident was a sign of misfortune. About 1000, his son Leif Ericson led what was probably the first voyage to the mainland of North America.

Most information about Eric the Red comes from two Icelandic stories written in the late 1100's or the 1200's, *Eric's Saga* and *The Greenlanders' Saga.* During the 1960's, archaeologists uncovered several stone and turf buildings from the early colonies, including Eric's house at Brattahlid. William A. Chaney

See also **Ericson, Leif; Greenland** (History); **Vikings** (The Norwegian Vikings).

Erickson, Arthur Charles (1924-), a Canadian architect, became noted for buildings that dramatically harmonize with the landscape. Many of Erickson's designs were built in or near Vancouver, British Columbia, and reflect the English, American Indian, and Japanese traditions of Western Canada.

In the 1960's, Erickson designed Simon Fraser University on a mountaintop overlooking Vancouver. Erickson used simple geometric forms that recall Japanese design, but the colors and some of the shapes capture the feeling of the hills and mountain peaks of Western Canada. Erickson's use of concrete, glass, and wood in the buildings further unites the structures with their natural surroundings. A picture of part of the campus appears in the introduction to the **Architecture** article.

In 1969, Erickson designed the main building of the University of Lethbridge in Alberta. The building resembles a horizontal ribbon of concrete that blends with the flat natural surroundings. In the late 1970's, he designed the Government Center for downtown Vancouver. It includes waterfalls, landscaped hills, and parks. His Canadian Embassy (1989) in Washington, D.C., features a complex series of elemental shapes set within a giant open cage. Erickson was born in Vancouver. Nicholas Adams

Ericson, Leif (A.D. 980?-1025?), was a Norse explorer who led what was probably the first European expedition to the mainland of North America. He was the son of Eric the Red, who established the first settlement in Greenland. Leif Ericson became the leader of this settlement after his father's death. His life was recorded in long Icelandic stories called *sagas.* His name is also spelled *Eriksson* or *Eiriksson.*

Ericson was born in Iceland, near what is now Búdardalur. His family sailed to southern Greenland about 985, and his father founded a settlement near present-day Julianehåb. About 999, Ericson sailed to Iceland and then to Norway, where he became a Christian. Ericson returned to Greenland the following year and preached Christianity in his father's pagan settlement.

Ericson sailed west from Greenland about 1000 to seek a land that had been sighted by a Norse sea captain, Bjarni Herjolfsson. According to the sagas, Ericson and his 35 men first landed at a level stone area that he named *Helluland* (Flat Rock Land). He then sailed farther south to a heavily wooded region that he called *Markland* (Forestland). He continued south and went ashore at a place where he found grapes growing. The men made wine from the grapes, and Ericson named the place *Vinland* (Wineland). Some historians think the fruit may have been cranberries or gooseberries.

Ericson and his men spent the winter in Vinland. They built a large house and a shed to protect their ship. They cut logs to bring back to Greenland, where trees were scarce. On the return trip, they rescued 15 victims of a shipwreck, who gave Ericson their cargo as a reward. This cargo, plus the logs, helped Ericson become rich. Eric the Red died soon after his son's return. Ericson stayed in Greenland to govern the settlement.

No one knows exactly where Ericson landed on his voyages because he made no maps. Some historians believe he landed first on Baffin Island and then sailed to Labrador. They think that Vinland was in northern New-

foundland, where Norwegian archaeologists found the ruins of an old Norse settlement in the early 1960's. However, other scholars believe Ericson sailed farther south, and that Vinland was near Cape Cod.

Other explorers sailed from Greenland to Vinland for about 15 years after Ericson's discovery. His brother, Thorwald, was killed by an Indian on one expedition. Norse exploration of America may have ended because of Indian attacks. Leif Ericson Day is observed in the United States on October 9. Franklin L. Ford

See also Eric the Red; Vikings; Vinland.

Ericsson, John (1803-1889), was a Swedish-born American engineer. He made many improvements in heating engines, ships, and locomotives. Ericsson's chief accomplishment was introducing screw propellers for use in place of paddle wheels on ships.

Ericsson was born in Värmland province, Sweden. He showed great mechanical ability at an early age. From age 13 to 17, Ericsson worked as an engineering apprentice on the Göta Canal in Sweden. He then served for six years as a surveyor in the Swedish army.

In 1826, Ericsson went to London, where he attempted to develop an engine that used heated air instead of steam. This effort failed, but he succeeded with other projects. Ericsson developed improved boilers and condensers for steam engines, designed an early steam-powered locomotive, and devised a machine for automatically cutting metal files. In 1833, he began experimenting with screw propellers, and in 1837, he built the first propeller-driven commercial ship.

Ericsson came to the United States in 1839 and became a U.S. citizen in 1848. There he designed a number of vessels, including the *Princeton* (1844), the first propeller-driven warship. He won fame for his design and construction of the *Monitor* (1862), one of the earliest ironclad warships. The ship also had a revolving gun turret. Its Civil War clash with the *Merrimack,* then called the *Virginia,* marked the first battle between ironclad ships. Terry S. Reynolds

See also Monitor and Merrimack; Propeller.

Erie, *EER ee* (pop. 103,717; met. area pop. 280,843), is the fourth largest city in Pennsylvania. Only Philadelphia, Pittsburgh, and Allentown have more people. Erie is in northwestern Pennsylvania, on the south shore of Lake Erie. It is the state's only lake port. For location, see Pennsylvania (political map).

Erie is laid out in a series of squares. Perry Square, the most prominent one, includes the City Hall and a federal courthouse. Many stately mansions stand near the square. One is the main building of Gannon University. Erie is also the home of Mercyhurst College. Pennsylvania State University at Erie—Behrend College is near the city. Erie's industries include shipping, tourism, and the manufacture of locomotives, plastics, and writing paper. Presque Isle State Park, on a peninsula near the city, has beaches, boating areas, hiking trails, and picnic areas. The park attracts many tourists to Erie.

Erie was founded as a town in 1795. Most of the ships of Commodore Oliver Hazard Perry's fleet, which defeated the British on Lake Erie during the War of 1812, were built in Erie. A restoration of Perry's flagship, the *Niagara,* is on exhibit in the city. Erie became a city in 1851. It is the county seat of Erie County. William C. Rense

Erie, Lake. See Lake Erie.

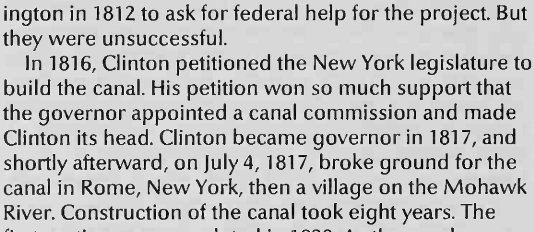
Erie Canal, *EER ee,* was the first important national waterway built in the United States. It crossed New York from Buffalo on Lake Erie to Troy and Albany on the Hudson River. Completed in 1825, the canal joined the Great Lakes system with the Atlantic Ocean. It provided a route over which manufactured goods and settlers could flow into the West and timber and agricultural products could pour into the East. The canal cut freight rates between Buffalo and New York City by more than 90 percent and helped New York City become the nation's leading port during the 1800's. The building of the canal was paid for by the state of New York. It cost $7,143,789, but it soon earned its price many times over.

The original canal was 363 miles (584 kilometers) long. It was 28 feet (8.5 meters) wide at the bottom, 40 feet (12 meters) wide at the top, and 4 feet (1.2 meters) deep. It could carry barges that were 80 feet (24 meters) long and 15 feet (4.6 meters) wide, with a draft of $3\frac{1}{2}$ feet (1.1 meters). The canal had 83 locks, which raised vessels on the canal about 565 feet (172 meters) from the Hudson River to Lake Erie. Barges were towed through the canal by horses and mules on shore. The canal was enlarged several times between 1835 and 1862.

The development of railroads made the canal less important after 1865. Business began to fall off. In 1903, the people of New York voted to make the canal part of a great modern waterway. The canal was linked with three shorter canals in New York to form the New York State Barge Canal System. This system, which is 524 miles (843 kilometers) long, opened in 1918. See New York State Barge Canal System.

The building of the Erie Canal. For a hundred years before the Erie Canal was built, people had been talking about a canal that would join the Great Lakes and the Atlantic Ocean. The man who planned the Erie Canal and carried the plans through was De Witt Clinton. Those who opposed the canal laughingly called it "Clinton's Ditch." Clinton and Gouverneur Morris went to Washington in 1812 to ask for federal help for the project. But they were unsuccessful.

In 1816, Clinton petitioned the New York legislature to build the canal. His petition won so much support that the governor appointed a canal commission and made Clinton its head. Clinton became governor in 1817, and shortly afterward, on July 4, 1817, broke ground for the canal in Rome, New York, then a village on the Mohawk River. Construction of the canal took eight years. The first section was completed in 1820. As the canal grew, towns along its course prospered. Utica, Syracuse, Rochester, and Buffalo became major cities.



WORLD BOOK map

Location of the Erie Canal

Completion of the canal. Clinton was governor again when the canal was completed in 1825. The first barge to travel its entire length, the *Seneca Chief,* left Buffalo on Oct. 26, 1825, and arrived in New York City on November 4. Clinton was on board. The barge was greeted all along the way by enthusiastic crowds.

At first, travel on the canal was slow. The famous editor Horace Greeley wrote that passengers traveled a mile and a half an hour on the Erie Canal for a cent and a half a mile. But fast passenger boats could travel 100 miles (160 kilometers) a day. Michael K. Heiman

See also **Clinton, De Witt.**

Erikson, Erik Homburger (1902-1994), was an American psychoanalyst. He became best known for his ideas on how human beings develop a sense of *identity*—that is, the awareness one has of oneself as a whole person.

Erikson based his ideas on the theories of Austrian psychoanalyst Sigmund Freud, who emphasized the importance of early childhood for all later development. However, Erikson modified Freud's ideas, stressing the continual development of human beings throughout an eight-stage life cycle. Freud focused on the psychological and biological aspects of development. Erikson said that social and cultural influences also are significant to development.

Erikson became widely known for his studies of adolescence, chiefly the idea of an adolescent *identity crisis.* Such a crisis may occur when an adolescent struggles with inner conflicts before gaining a sense of purpose and moving into adulthood. Erikson expressed his central ideas on adolescence in the books *Childhood and Society* (1950) and *Identity: Youth and Crisis* (1968).

Erikson also gained praise for biographies that examine the psychological development of well-known historical figures. These books include *Young Man Luther* (1958), which depicts German religious reformer Martin Luther, and *Gandhi's Truth* (1969), which focuses on the Indian spiritual and political leader Mohandas K. Gandhi.

Erikson was born in Frankfurt (am Main), Germany. His parents were of Danish ancestry. In 1933, Erikson graduated from the Vienna Psychoanalytic Institute. That same year, he and his family moved to the United States. Erikson taught at Harvard University, Yale University, and the University of California at Berkeley. Hannah S. Decker

Erin. See **Ireland.**

Eritrea, *EHR ih TREE uh,* is a small country on the northeast coast of Africa. It stretches along the Red Sea, between Sudan and Djibouti. Ethiopia lies to the south. Most of Eritrea's people are farmers or herders. The country has little industry. Asmara is Eritrea's capital and largest city. The country's official name is the State of Eritrea.

Eritrea was once a part of the Aksum Kingdom. The kingdom reached its height as a trading and cultural center between the A.D. 300's and 600's. Italy gained control of Eritrea in the late 1800's. The United Kingdom took over the area in 1941, during World War II. In 1952, Eritrea became part of Ethiopia.

In 1961, civil war broke out between Eritrean rebels, who wanted independence for their land, and Ethiopian government troops. The war finally ended in 1991, with a victory by Eritrean and other rebels. Eritrea formally achieved independence in 1993.

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Asmara is the capital and largest city of Eritrea. The city has many Western-style buildings dating from the early and middle 1900's, when Eritrea was a colonial possession of Italy's.

Government. A president heads the government of Eritrea. The president is elected by the country's legislative body, the 150-member National Assembly. Members of the National Assembly are elected by the people.

The People's Front for Democracy and Justice (PFDJ) is Eritrea's strongest political party. Formerly called the Eritrean People's Liberation Front (EPLF), the organization led the fight for Eritrea's independence.

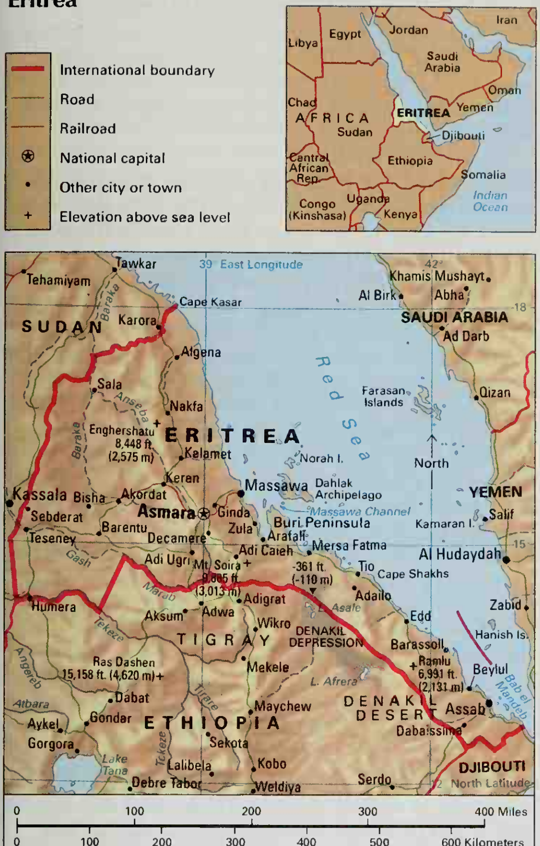
People. Most Eritreans are descendants of people from the Arabian Peninsula and from the Nile River region of Sudan who came to the area starting about 2000 B.C. Tigrinya is Eritrea's chief language. Tigre is the second most common language. Arabic is spoken on the coast. Groups of herders speak Afar or other languages.

About 80 percent of the people of Eritrea are farmers or herders. Farming families live in walled or fenced settlements. The homes have flat thatched roofs or peaked roofs made of corrugated iron. Most farm households

Facts in brief

Capital: Asmara.
Principal language: Tigrinya.
Area: 45,406 mi² (117,600 km²). *Greatest distances*—northwest-southeast, 510 mi (821 km); northeast-southwest, 290 mi (467 km). *Coastline*—620 mi (1,000 km).
Elevation: *Highest*—Mount Soira, 9,885 ft (3,013 m) above sea level. *Lowest*—Denakil Depression, about 360 ft (110 m) below sea level.
Population: *Estimated 2002 population*—4,044,000; density, 89 per mi² (34 per km²); distribution, 84 percent rural, 16 percent urban. *1984 census*—2,748,304.
Chief products: *Agriculture*—barley, dairy products, lentils, millet, sorghum, teff, wheat. *Manufacturing*—construction materials, leather goods, processed foods, salt.
Flag: The flag has a red triangle across the middle, bearing a yellow wreath and olive branch; a green triangle at the top; and a light blue triangle at the bottom. Adopted in 1993. See **Flag** (picture: Flags of Africa).
Money: Basic unit—nakfa.

Eritrea



WORLD BOOK map

consist of an extended family that may include up to several dozen relatives. Farmers meet for occasional market days, festivals, or at regional village towns. Herders move from place to place with their livestock.

About half the Eritreans are Christians. Most of the others, including many herders, are Muslims. Coptic Christianity, a form of Christianity that originated in Egypt, was brought to the country in the A.D. 300's. Islam came to Eritrea in the 600's.

Eritrea's educational system was shaped under Italian rule and expanded under British rule. The long civil war severely disrupted the educational system. As a result, a majority of Eritrea's children have not received much formal education. Illiteracy remains a serious problem in the country. Eritrea has one university, the University of Eritrea, in Asmara.

Land and climate. Eritrea covers 45,405 square miles (117,598 square kilometers). It stretches along the Red Sea from Cape Kasar to the Strait of Bab el Mandeb—a distance of about 620 miles (1,000 kilometers). A coastal plain along the Red Sea ranges from 10 to 40 miles (16 to 64 kilometers) in width. The plain rises to highlands in the central part of Eritrea. Mount Soira, in the highlands, is the country's highest peak. It rises 9,885 feet (3,013 meters) above sea level. The highlands drop to lowlands in the west. Denakil Desert covers the southeastern part of the country.

The country's main rivers flow westward, cutting valleys through the central highlands and western lowlands. Eritrea's main rivers include the Baraka and the Gash. The Gash is called the Marab for part of its length.

Temperatures average 80 °F (27 °C) along the coast and 60 °F (16 °C) in the highlands. The coast receives about 6 to 10 inches (15 to 25 centimeters) of rain a year, and the highlands receive up to 24 inches (61 centimeters). In most parts of the country, the heaviest rains occur in June and July.

Economy. Eritrea's economy suffered severely during the civil war with Ethiopia. Many roads and rail lines were badly damaged or destroyed. Industrial production declined sharply. Drought and refugee movements ruined much farmland. The economy began to improve somewhat after the war, but it was again disrupted during a border conflict that broke out between Eritrea and Ethiopia in the late 1990's.

Farming and herding rank as Eritrea's chief economic activities. Farming is important in the central highlands, and herding is concentrated along the coast and in the western lowlands. The country's main farm products include barley, dairy products, lentils, millet, sorghum, and wheat. Farmers also grow *teff,* a grain that is common only in Eritrea and Ethiopia. Herders raise cattle, goats, and sheep.

Eritrea's agriculture has suffered from recurring periods of drought. Irrigation, which was introduced during Italian rule, has relieved the problem somewhat. Commercial fishing in the Red Sea contributes to the country's economy.

Asmara is the main center of production. The country's chief manufactured or processed products include construction materials, leather goods, processed foods, and salt.

Eritrea has petroleum deposits. The country is strategically located for trade. Massawa and Assab rank as its chief ports.

History. About 2000 B.C., people from the interior of Africa settled in what is now Eritrea. About 1000 B.C., people began arriving from the Arabian Peninsula.

The Aksum Kingdom became the first important state in the area. It gained importance about A.D. 50 and reached its greatest power between the 300's and 600's. During the 600's, Muslims gained control of the area.

The coastal region of Eritrea came under the rule of the Ottoman Empire in the 1500's. About the same time, kingdoms from what are now Ethiopia and Sudan fought over the rest of Eritrea. In the 1800's, Egypt, France, and Italy attempted to gain control of Eritrea.

In 1882, Italy occupied the port of Assab. In 1885, it occupied the port of Massawa and other regions along the coast. By 1889, Italy had conquered all of Eritrea. Italy used Massawa as a base for an invasion of Ethiopia. Ethiopian Emperor Menelik II defeated the Italian forces in 1896. But Italy conquered Ethiopia in 1935.

During the period that Eritrea was under Italy's control, the Italian government invested in agricultural plantations and established a number of industries. About 60,000 Italians settled in Eritrea.

British forces drove the Italians out of Africa in 1941, during World War II. A British military administration then began governing Eritrea. In 1950, the United Nations General Assembly adopted a resolution that Eritrea

become part of Ethiopia, but govern itself. The resolution was put into effect in 1952.

The Ethiopian government, led by Emperor Haile Selassie, sought to undermine Eritrea's self-government by banning political parties and trade unions in Eritrea. But the Eritreans started a political movement called the Eritrean Liberation Front (ELF). In 1961, civil war broke out between the ELF and the Ethiopian government. In 1962, Ethiopia declared Eritrea to be a province of Ethiopia.

In 1970, the Eritrean People's Liberation Front (EPLF) was formed. The EPLF gradually replaced the ELF as Eritrea's main political organization. In 1974, Ethiopian military leaders removed Haile Selassie from power. They set up a government called the Dergue. The EPLF tried to negotiate with the Dergue for Eritrean independence. But the talks failed, and the civil war continued.

In 1987 and 1988, victories against Ethiopian government forces by EPLF forces and forces from the Tigray region, south of Eritrea, led to a collapse of central government rule throughout much of Ethiopia.

In 1991, Eritrean rebels joined with a group of rebels led by Tigrayans to overthrow Ethiopia's government. The rebel group led by Tigrayans established a new government for all of Ethiopia except Eritrea. The Eritreans formed their own government. They formally declared independence from Ethiopia on May 24, 1993, after a *referendum* (popular vote) in favor of independence. Eritrea adopted a new constitution in 1997.

When Eritrea achieved independence, a section of the border with Ethiopia had not been clearly defined. Eritrea and Ethiopia fought a bloody war over this disputed area from May 1998 to June 2000, when the two sides signed a cease-fire agreement. They signed a formal peace treaty in December 2000. The treaty included a provision that established a commission to identify the border between the two countries. Stephen K. Commins

See also **Asmara; Ethiopia** (History).

Ermine, *UR muhn,* is a small animal that lives in northern regions of North America, Europe, and Asia. In North America, ermines are sometimes called *short-tailed weasels.* In Europe, they are called *stoats.* North American ermines are found from the Arctic south to Pennsylvania and northern Virginia in the east and to central California and New Mexico in the west. The ermine is a member of the weasel family, which also includes minks, badgers, otters, wolverines, and skunks.

Most ermines measure about 7 to 13 inches (18 to 33 centimeters) long and weigh about 2 to 10 ounces (57 to 285 grams). The males are larger than the females. An ermine has silky fur. During the late spring and summer, the color of the fur is brown above and white below. The tail has a black tip. The ermine sheds its fur each autumn and grows a new coat that is pure white, except for the black tip on the tail. During the white color phase, the animal is often trapped for its fur. In the Middle Ages, nobles used ermine fur for full-length coats and capes. Today, the fur is rarely used in clothing.

Ermines live in a variety of habitats, including riverbanks, the edges of forests, and in wet meadows, marshes, and ditches. Ermines feed primarily on small rodents and rabbits. They generally live alone as adults.

A female ermine has one litter of 3 to 13 young each year, usually in April. The mother usually raises the young by herself. Ermines grow rapidly. Some females are fully grown and able to mate during their first summer. Males mature later than females. Ermines can live for 4 to 7 years. The chief enemies of ermines include owls, hawks, cats, dogs, and foxes. Gary A. Heidt

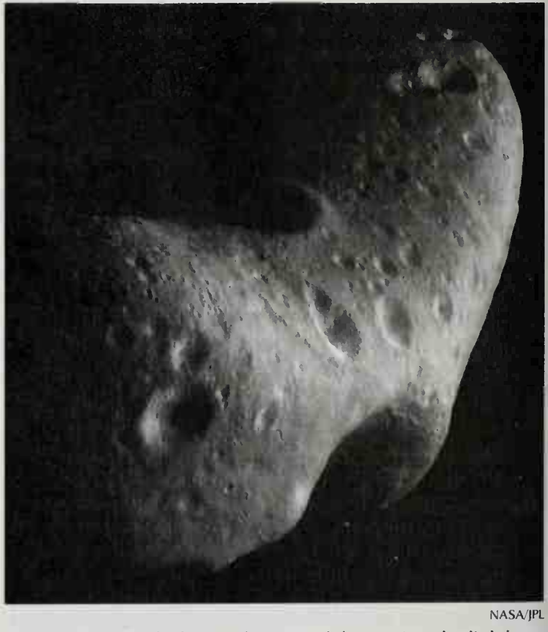
Scientific classification. The ermine belongs to the weasel family, Mustelidae. It is *Mustela erminea.*

See also **Fur; Weasel.**

Ernst, Max (1891-1976), was a German artist associated with the development of the Dada and Surrealist movements. He joined with several other artists and writers as a leader of the Dada movement, founded in 1916. He created Dada works by combining photographs, scientific and technical illustrations, and newspaper clippings into pasted compositions called *collages.* His images often deal with symbolic meanings taken from philosophy and psychiatry, which he studied as a young man. Ernst moved to Paris in 1924 and helped to found the Surrealist movement there. His Surrealist works suggest nightmares and hallucinations. They often portray mysterious and menacing forests. Ernst was born on April 8, 1891, in Brühl. He lived in the United States in the 1940's. See also **Dadaism; Surrealism** (picture). Pamela A. Ivinski

Eros is one of the largest asteroids that come close to Earth. Eros's distance from the sun ranges from 105 million to 166 million miles (169 million to 267 million kilometers)—1.13 to 1.78 times Earth's average distance from the sun. The asteroid completes one orbit around the sun every 1.76 earth-years. Although its orbit does cross that of Earth, scientists estimate that Eros has only a tiny chance of hitting Earth in the next 100 million years.

Eros is shaped like a potato, and it is 21 miles long, 7 miles wide, and 7 miles high (34 by 11 by 11 kilometers). It is made up of rocky material. The average density of Eros is 2.67 grams per cubic centimeter, slightly less than half that of Earth. Eros's low density suggests that



NASA/JPL

Eros is an asteroid whose orbit around the sun is only slightly larger than Earth's orbit. Eros is about 21 miles (34 kilometers) long. It is made up of rocky material.

about 30 percent of the asteroid's volume consists of crevasses and cracks. Eros spins end-over-end, rotating once every 5 hours 16 minutes. Areas of the surface in sunlight have a temperature of about 210 °F (100 °C), while areas in darkness are as cold as −240 °F (−150 °C).

Impacts of meteorites and other asteroids have created countless craters on Eros, and have broken the surface into a network of cracks and troughs. Strewn across the surface are boulders that range from the size of a chair to the size of a house.

The German astronomer Gustav Witt and the French astronomer August H. P. Charlois independently discovered Eros in 1898. The space probe Near Earth Asteroid Rendezvous-Shoemaker (NEAR-Shoemaker) studied the asteroid and landed on it in 2000. Louise M. Prockter

Eros, in mythology. See **Cupid.**

Erosion, *ih ROH zhuhn,* is a natural process by which rock and soil are broken loose from the earth's surface at one location and moved to another. Erosion changes land by wearing down mountains, filling in valleys, and making rivers appear and disappear. It is usually a slow and gradual process that occurs over thousands or millions of years. But erosion can be speeded up by such human activities as farming and mining.

How erosion occurs. Erosion begins with a process called *weathering.* In this process, environmental factors break rock and soil into smaller pieces and loosen them from the earth's surface. A chief cause is the formation of ice. As water freezes, it expands with great force. As a result, when it freezes inside the crack of a rock, it can break the rock apart. Other major agents of weathering include chemicals; living organisms; the movement of air, ice, and water; and heat from the sun.

After materials have been loosened by weathering, they are moved to new locations. For example, winds lift particles from the earth's surface and can carry them over great distances. Glaciers transport materials embedded in them. Raindrops that splash against sloping land move soil particles downhill. Water currents carry materials down a riverbed or out to sea.

Effects of erosion. Erosion can be both helpful and harmful. It benefits people by contributing to the formation of soil through the breaking up of rock. It causes rich soil to be deposited on valley floors and at the mouths of rivers. Erosion also has produced some of the world's most spectacular geological formations. The Grand Canyon, for instance, has been created over the course of millions of years by erosion from the Colorado River. See **Grand Canyon.**

One of the most harmful effects of erosion is that it robs farmland of productive topsoil. For this reason, it is one of the leading threats to the food supply. Erosion can also wash valuable fertilizers from farmland and carry pollution-causing agricultural chemicals into lakes and rivers. Eroded soil can clog irrigation ditches, ponds, and reservoirs. Gullies caused by flowing water may ruin fields by making them too small to farm with tractors and other modern equipment.

Controlling erosion. Although erosion is a natural process, people can influence the extent to which it occurs. Soil erosion increases, for example, when land is cleared and cultivated, because trees and other plants shield soil from wind and rain. Plant roots and the remains of dead plants also help to hold soil in place. Farmers can thus reduce erosion by keeping idle fields planted with such thickly growing *cover crops* as alfalfa or grass. Many farmers also decrease erosion through the use of *no-till* and *conservation tillage* techniques, in which remains of the previous crop are left on the soil surface. Other conservation methods include *contour plowing, strip cropping,* and *terracing.* See **Conservation** (Soil conservation). John M. Laflen

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Canyon	Glacier	Soil
Dust storm	River	Water (How water shapes the earth)
Earth (Earth's rocks)		

Erving, Julius (1950-), became one of the most exciting and popular players in the National Basketball Association (NBA). Erving, who was 6 feet 6 inches (198 centimeters) tall, played forward and guard. He became noted for his outstanding jumping ability and spectacular dunk shots. Erving was nicknamed *Dr. J.*

Julius Winfield Erving, Jr., was born on Feb. 22, 1950, in East Meadow, New York. He attended the University of Massachusetts from 1968 to 1971, when he left to play for the Virginia Squires of the American Basketball Association (ABA). In 1973, Erving was traded to the New York Nets of the ABA. In 1976, the Nets sold Erving to the Philadelphia 76ers of the NBA. Erving was named the NBA's Most Valuable Player for the 1980-1981 season. He retired after the 1986-1987 season. Bob Logan

See also **Basketball** (picture).

Eryops, *EH ree ahps,* was a prehistoric amphibian that inhabited swamps of what is now North America. It lived about 270 million years ago, during the Permian Period and long before the dinosaurs. The name *Eryops* means *long face.* It describes the animal's broad, elongated head.

Eryops ranked among the larger land animals of its time, growing more than 5 feet (1.5 meters) in length. Four short, strong legs supported the creature's thick body. Its powerful jaws held many sharp teeth.

Like modern amphibians, *Eryops* lived part of its life in the water and part on land. It probably laid its eggs in water. A young *Eryops* likely breathed by means of gills, but it lost its gills as an adult and breathed with lungs. Scientists believe *Eryops* may have been more capable of living and moving on land than were other amphibians. *Eryops* ate mostly fish, but it also preyed on small amphibians and reptiles. It probably captured its prey both on land and in water.

American paleontologist Edward Drinker Cope named *Eryops* in 1887. The animal's fossils have been found in New Mexico, Oklahoma, and Texas.

Kenneth Carpenter

See also **Prehistoric animal** (picture: Animal life of the Paleozoic Era).

Erysipelas, *EHR uh SIHP uh luhs,* is a skin infection that chiefly affects infants, young children, and elderly people. It causes a painful thickening and tightening of the skin and spreads rapidly during one or two days. The infected area appears red and shiny, with a slightly raised border. If left untreated, erysipelas can lead to serious internal infections, especially in newborns.

Most cases of erysipelas are caused by bacteria of a type called *group A beta-hemolytic streptococci* (see

Streptococcus). The infection begins when the bacteria enter the skin, typically through an open cut or scratch. The bacteria then invade the surrounding skin. Erysipelas most often affects the face, but it may affect any area of skin. The infection may also cause fever and vomiting. The infection normally clears up a few days after treatment with an antibiotic, usually penicillin or erythromycin. Untreated cases may last several weeks.

Serious complications can occur if erysipelas spreads inside the body. The infection may lead to *septicemia* (blood poisoning) or to a kidney disease called *acute glomerulonephritis* (see **Blood poisoning; Nephritis**).

Paul R. Bergstresser

Erythema, *EHR uh THEE muh,* is a redness of the skin. It is related to an increase in the amount of blood present in the *capillaries* (small blood vessels) of the skin. The skin reacts to slight injury or irritation with erythema, which can be produced in many ways. For example, exposure of the skin to sunlight for a short time will cause erythema. Longer exposure results in the formation of blisters. A sharp slap will also produce erythema in the contacted area. Erythema is also a symptom of some diseases. Paul R. Bergstresser

Erythromycin, *ih RIHTH roh MY sihn,* is an antibiotic used to treat scarlet fever, strep throat, and many other bacterial infections. Erythromycin is also effective against Legionnaires' disease and certain other types of pneumonia (see **Legionnaires' disease**). Many of these infections are more commonly treated with one of the penicillins, but erythromycin is useful for patients allergic to penicillins. Erythromycin fights bacteria by blocking the process by which they produce proteins. This blockage prevents the bacteria from multiplying, and the body eventually destroys them. Erythromycin was discovered in 1952. It is relatively safe and seldom causes serious side effects. See also **Antibiotic.** N. E. Sladek

Esau, *EE saw,* was the son of Isaac and Rebecca, and the elder twin brother of Jacob in the Bible. He is a main character in stories in Genesis 25-33. The best known are Jacob's buying his birthright for a bowl of stew (Genesis 25:27-34) and the loss of his blessing through the plotting of Rebecca and Jacob (Genesis 27). Esau was reconciled to Jacob after Jacob's return to Canaan (later called Palestine) 20 years later. Biblical history regards Esau as the founder of the Edomite nation. See also **Edom; Isaac; Jacob.** Carole R. Fontaine

Escalator is a moving stairway that transports people from one floor or level to another. Escalators are found in airports, subway stations, stores, and other commercial and public buildings.

An escalator resembles a conveyor belt with steps attached. Each step has two pairs of wheels on the underside. The wheels travel on two sets of tracks. The steps are pulled along the tracks by chains that move around gears located at the top and bottom of the escalator. An electric motor powers the steps. The steps of an escalator are formed where the two sets of tracks run alongside each other. At the top and bottom of an escalator, the two sets of tracks level off and separate, causing the steps to flatten. They form a moving platform that enables passengers to get on or off at the landing without tripping. Other safety features include moving handrails and a grooved tread on the steps. Safety devices stop an escalator if anything gets caught in the steps.

Some escalators can carry up to 4,500 people an hour. The movement of the steps can be reversed during rush hours, when most traffic moves in one direction.

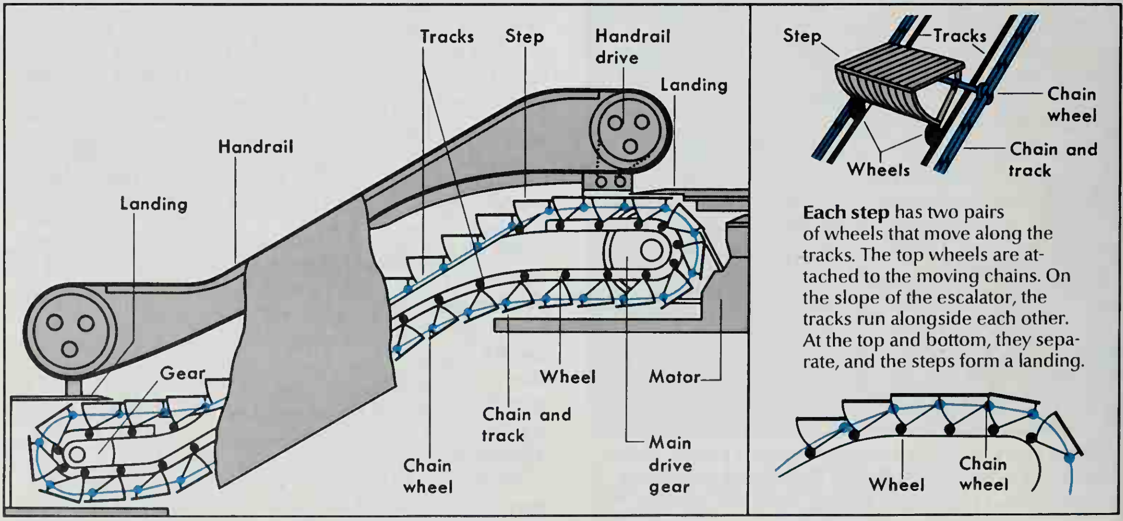
The escalator developed chiefly from the work of two American inventors, George H. Wheeler and Jesse W. Reno. In 1892, Wheeler patented a design for a moving stairway that had flat steps and landings at the sides. He later sold the patent to another inventor, who improved the design. Reno developed an inclined conveyor belt with a grooved tread for steady footing. The first operating escalator, based on Reno's design, was used in a New York City elevated train station in 1900. In 1922, the Otis Elevator Company combined the flat steps and the grooved tread to form the modern escalator.

Moving sidewalks are similar to escalators but operate only on flat or slightly inclined surfaces. A moving

How an escalator works

An escalator is a series of steps that are pulled by chains along two sets of tracks. The steps, which are powered by an electric motor, move around gears located at the top and bottom.

WORLD BOOK illustrations by Steven Liska



Each step has two pairs of wheels that move along the tracks. The top wheels are attached to the moving chains. On the slope of the escalator, the tracks run alongside each other. At the top and bottom, they separate, and the steps form a landing.

sidewalk consists of a conveyor belt made up of an endless series of flat platforms. Cynthia J. DiTallo

Escheat, *ehs CHEET,* is the turning over of property to the state when no owner claims it. Such a right may be exercised by the state when a person dies without a will or when the person has no spouse or other relative to be the heir. In this case, the estate reverts to the state. In some states, bank deposits and bank dividends which have been unclaimed for a certain period may escheat to the state. See also **Estate**. William M. McGovern

Eschenbach, Wolfram von. See **Wolfram von Eschenbach**.

Escher, M. C. (1898-1972), was a Dutch artist known for his intricate, detailed prints. Most of his work consists of black-and-white lithographs and woodcuts. In his graphic art, Escher explored the complex relationship of shapes and figures to space. He often experimented with the repetition of interlocking figures, using black and white to create dimension. His prints also portray mirror images of cones, spheres, and cubes as well as connecting rings and continuous spirals. Escher used these designs to create such illusory images as circular waterfalls and endless staircases.

An M. C. Escher print shows the geometric designs and optical illusions that are typical of his style. In *Waterfall, shown here,* a continuous waterfall seems to flow from water moving uphill.

Maurits Cornelis Escher was born on June 17, 1898, in Leeuwarden, the Netherlands. He studied at the School for Architecture and Decorative Arts in Haarlem, intending to become an architect. In a short time, however, he turned to the decorative and graphic arts. Roger Ward

Escherichia coli. See **E. coli**.

Escobar, Marisol. See **Marisol**.

Escobedo v. Illinois, *ehs koh BEE doh,* was a landmark decision of the Supreme Court of the United States concerning the rights of people accused of crimes. In this 1964 ruling, the court stated that police who question suspects must advise them of their right to consult a lawyer. If the police do not do so, the suspects' answers may not be used as evidence.

In 1960, Danny Escobedo, a Mexican American laborer, had been arrested in connection with a murder. While questioning Escobedo, Chicago police refused to let him confer with his attorney. They also did not inform him of his constitutional right to remain silent. A jury convicted Escobedo chiefly because of answers he gave during this interrogation.

The Supreme Court ruled that Escobedo's statements could not be used to convict him. The court based its decision on the defendant's right to "assistance of counsel," guaranteed by the Sixth Amendment to the Constitution of the United States. The ruling became controversial, partly because the court had failed to establish clear guidelines for police procedures. The court clarified its position in a 1966 case, *Miranda v. Arizona* (see **Miranda v. Arizona**). Stanley I. Kutler

Escorial, *ehs KAWR ee uhl,* is a large complex of buildings and courtyards about 30 miles (48 kilometers) northwest of Madrid, Spain. The Escorial consists of a domed church, a college, a monastery, and a palace surrounded by a wall. The Escorial was erected during the reign of Philip II. Construction began in 1563 and was completed in 1584. The complex stands as a monument to Roman Catholicism and serves as the burial place of Philip II and many other kings of Spain.

The Escorial is noted for its order, simplicity, and austerity. It is built of yellow-gray granite from a nearby quarry. The church and a monastery cloister called the Court of the Four Evangelists are especially grand in scale and character. J. William Rudd

See also **Spain** (Architecture).

Escrow, *EHS kroh,* is cash, a document, or other property given to one person for delivery to someone else when a certain condition is met. The holder of the property is called the *escrow agent* or *escrow holder.*

When one party to a contract gives property to an escrow agent, the second party to the contract may feel sure that the contract will actually be carried out. As a result, the second party may be encouraged to perform his or her part of the contract.

The escrow holder is an agent of both the party who deposits the escrow and the party to whom it will be delivered when the escrow condition is met. Property given to the agent cannot be returned without the approval of both parties. Once the condition of the escrow is met, the escrow holder must deliver the property according to the escrow agreement. James L. Winokur

Esfahan. See **Isfahan**.

Eshkol, *EHSH kawl,* **Levi,** *LEE vee* (1895-1969), helped found the state of Israel and served as prime minister from 1963 until his death. Eshkol was a capable administrator, political leader, and statesman who served in such posts as director of the ministry of defense, minister of agriculture, and minister of finance. While he was prime minister, Israel fought the Six-Day War against the Arab states in 1967. Eshkol favored Israeli cooperation with Arab states to develop the Middle East.

Eshkol was born Levi Shkolnik on Oct. 25, 1895, in Ukraine (then under Russian control). He joined the Zionist movement as a young man. In 1914, he moved to Palestine and worked as a farmer. He helped form the Histadrut (General Federation of Labor) in 1920 and the Mapai (Israel Workers' Party) in 1930. In the 1930's, he helped Jews in Germany move to Palestine. He helped build up the Haganah, the Jewish underground organization that fought against British mandate forces and against Palestinian Arabs opposed to the formation of a Jewish state in Palestine (see **Palestine**). Ellis Rivkin

Eskimo. See **Inuit**.

Eskimo dog. See **America Eskimo dog**.

ESOP. See **Employee stock ownership plan**.

Esophagus, *ee SAHF uh guhs,* also called *gullet,* is the muscular tube that carries food from the mouth to the stomach. The muscles in the walls of the esophagus contract in a wavelike manner, moving the food down to the stomach. Glands in the walls of the esophagus secrete mucus that helps the movement of food by providing lubrication.

A muscular ring called the *lower esophageal sphincter* surrounds the opening between the esophagus and the stomach. The sphincter normally keeps the stomach contents from flowing back into the esophagus. The stomach produces a digestive juice that, in most people, contains a strong acid called *hydrochloric acid.* If the sphincter fails to function properly, stomach acid may rise back into the esophagus, causing a painful burning sensation called *heartburn.* The acid may damage the esophagus, leaving open sores in its lining.

The human esophagus is about 10 inches (25 centimeters) long. The length varies greatly in different animals. The esophagus of fish is short, while that of giraffes is extremely long. Many birds have a saclike part of the esophagus called the *crop* for the temporary storage of food. Charles Liebow

See also **Alimentary canal; Digestive system; Heartburn; Human body** (Trans-Vision); **Stomach**.

ESP. See **Extrasensory perception**.

Esperanto, *EHS puh RAHN toh,* is the most widely used international language. L. L. Zamenhof, a Polish physician, devised Esperanto. He published a book about the language, *Lingvo Internacia* (1887), under the pen name Dr. Esperanto. The word *esperanto* means *one who hopes* in that language.

Esperanto has a simple, uniform structure. For example, the accent of a word always falls on the next-to-last syllable. Adjectives end in *a*, adverbs end in *e*, and nouns end in *o*. But when a noun is used as an object, an *n* is added at the end of the word. Plurals end in *j*. The basic vocabulary of Esperanto consists mainly of root words common to the Indo-European languages. The following sentence is written in Esperanto: *La astronauto, per speciala instrumento, fotografas la lunon.* The translation: *The astronaut, with a special instrument, photographs the moon.*

Critically reviewed by the Esperanto League for North America

Espionage, *EHS pee uh NAHZH,* or *EHS pee uh NIHJ,* is the act of spying on a country, organization, movement, or person. It involves a system of spies that governments and other groups send into an enemy area or a possible enemy area to gather information. The spies seek valuable military, political, scientific, and production facts and secrets. People spy for money, adventure, and love as well as for their country or to help a cause. Some are forced to spy against their will. They usually work as members of an organization through which they get instructions and send back information.

Espionage is one of the main information-gathering methods used in intelligence organizations. The agency evaluates and interprets information from its agents, researchers, and such mechanical devices as electronic eavesdropping equipment. Some governments also use spy planes and space-based satellites. This process produces knowledge that is useful to political and military leaders in their foreign and defense policies.

Counterespionage is set up to protect a country and its intelligence services against spying by hostile forces. A counterespionage agency seeks to prevent the theft of secret information and to detect the presence of spies within organizations. Such an agency works to discover and arrest hostile spies. It also may place its own spies in an opposing organization. An agency may try to get hostile spies to give it information about the enemy's system. Such spies are called *double agents.* All countries have counterespionage agencies.

History. Espionage is older than war. The first spies were probably prehistoric people who were curious about their neighbors' hunting techniques. The Bible tells of Moses's sending spies into Canaan. In modern times, Frederick the Great of Prussia is credited with originating systematically organized espionage.

George Washington's network of spies obtained intelligence and information for the Continental Army during the Revolutionary War in America (1775-1783). Allan Pinkerton directed espionage and counterespionage for the Union Army during the early days of the Civil War (1861-1865). Later, a Bureau of Information carried on this work. During World War II (1939-1945), the Office of Strategic Services (OSS) conducted government overseas espionage and intelligence operations. In 1947, Congress established the U.S. Central Intelligence Agency (CIA) to coordinate government intelligence activities and to carry on its own operations. In 1954, Congress passed a law making peacetime espionage against the United States punishable by death. The death penalty for espionage had been imposed previously only during wartime. Douglas L. Wheeler

See also **Central Intelligence Agency; Codes and ciphers; Intelligence service; Spy; Treason**.

Esposito, *EHS puh ZEE toh,* **Phil** (1942-), was one of the greatest scorers in National Hockey League (NHL) history. A center, Esposito led the NHL in goals six straight years, from 1969-1970 through the 1974-1975 season. During the 1970-1971 season, he scored 76 goals and 152 points (goals plus assists). Both marks were NHL records until Wayne Gretzky broke them.

Esposito played with the Chicago Blackhawks from the 1963-1964 season through the 1966-1967 season, before being traded to the Boston Bruins. In 1975, Esposito was traded to the New York Rangers, where he played until his retirement in 1981. He was general manager of the Rangers from 1986 to 1989 and also coached the team for portions of those years. From 1990 to 1998, Esposito served as president and general manager of the Tampa Bay Lightning. Philip Anthony Esposito was born Feb. 20, 1942, in Sault Ste. Marie, Ontario. Larry Wigge

Espy, Mike (1953-), became the first African American to serve as United States secretary of agriculture. He was appointed by President Bill Clinton in 1993 and served until the end of 1994. Before his appointment, Espy had represented Mississippi as a Democrat in the U.S. House of Representatives since 1987. He was the first African American representative from that state since the Reconstruction era of the 1860's and 1870's. In Congress, Espy served on the House Agriculture Committee, where he became known for his proposals to help poor farmers. He was also a member of the House Select Committee on Hunger and the House Budget Committee.

In 1997, Espy was charged with accepting gifts from companies regulated by the Department of Agriculture while he was its secretary. Espy pleaded innocent to the charges. A trial was held in 1998. Espy was found not guilty on all of the 30 charges brought against him. The trial judge had earlier dismissed eight other charges.

Albert Michael Espy was born in Yazoo City, Mississippi, on Nov. 30, 1953. He received a bachelor's degree from Howard University in 1975 and a law degree from Santa Clara University in 1978. Espy became an assistant secretary of the state of Mississippi in 1978. In 1984 and 1985, he was an assistant state attorney general.

Barbara A. Reynolds

Essay is a short, nonfictional composition that presents the writer's opinion or analysis of a particular subject. Essays make up a major form of literature that includes many types of writing, such as book reviews, magazine articles, and newspaper editorials.

There are two main kinds of essays, *personal essays* and *formal essays.* A personal essay is written in a casual, conversational style. A formal essay is carefully organized and more serious than a personal essay.

Personal essays were originated by Michel de Montaigne, a French writer of the 1500's. He was the first to establish the essay as a distinct form of literature. The word *essay* comes from *Essais* (1580), Montaigne's two-volume collection of writings. Montaigne called this collection *Essais,* a French word meaning *trials* or *attempts,* because his compositions are exploratory and informal. They are based mainly on personal experience and discuss such topics as idleness, judgment, and lying.

Joseph Addison and Sir Richard Steele, two English essayists of the early 1700's, wrote about the opinions and tastes of the English people. Addison composed clear, compactly written essays. Steele's essays are more spontaneous and conversational. Addison and Steele published and wrote essays for two periodicals, *The Tatler* (1709-1711) and *The Spectator* (1711-1712). These periodicals helped make the personal essay popular.

Charles Lamb, an English author of the early 1800's, wrote essays about the people and events in his life. Lamb's essays contain interesting insights and are written in a casual, sometimes humorous style.

Oliver Wendell Holmes, an American writer of the 1800's, composed witty personal essays. His best-known book, *The Autocrat of the Breakfast-Table* (1858), consists of 12 essays that combine imagination, humor, and scientific fact. These essays supposedly describe a breakfast conversation at a boarding house. However, they actually express Holmes's opinions on human nature, religion, science, and other topics.

H. L. Mencken was an American critic, journalist, and editor whose major essays were published in the early 1900's. His essays, written in a colorful, aggressive style, criticized the attitudes of the American middle class.

The American author E. B. White became one of the few writers of the middle and late 1900's to concentrate on personal essays. His writings have an informal, conversational style and deal with many topics.

Formal essays were developed by Sir Francis Bacon, an English philosopher and statesman of the mid-1500's and early 1600's. Bacon was the first English essayist. One of his major works was *Essays* (1597), a collection of 10 essays that explain how to lead a sensible life. These essays are short, impersonal, and informative, and they discuss such subjects as death, fear, truth, and wealth.

The English poet and essayist John Milton wrote the *Areopagitica* (1644), one of the finest examples of a formal essay. It is a persuasive appeal to Parliament to protect freedom of speech and of the press. It was printed as a pamphlet and distributed in London.

Alexander Pope, an English poet of the 1700's, wrote formal essays in verse. In *An Essay on Criticism* (1711), Pope used verse to explain how poetry should be criticized. He also discussed the works of several major poets in this informative, clearly written essay. Pope's other works include *An Essay on Man* (1733-1734) and *Moral Essays* (1731-1735).

The English critic William Hazlitt was one of the best writers of formal essays during the late 1700's and early 1800's. He wrote a collection of critical essays called *Characters of Shakespeare's Plays* (1817), in which he discussed the personalities of various characters in the dramas of William Shakespeare. He also wrote many fine personal essays.

Ralph Waldo Emerson was an important American essayist of the 1800's. He wrote many formal essays about morals and philosophy. Emerson's book *Nature* (1836) is an essay that explains the complex principles of transcendentalism, a philosophical movement that he helped establish in the United States.

Major modern American essayists include Stephen Jay Gould and Susan Sontag. Gould discusses scientific subjects. Sontag writes about many subjects, including politics, the arts, and popular culture. Marcus Klein

Each of the writers mentioned in this article has a biography in *World Book.*

Additional resources

Chevalier, Tracy, ed. *Encyclopedia of the Essay.* Fitzroy Dearborn, 1997.

Oates, Joyce C., and Atwan, Robert, eds. *The Best American Essays of the Century.* Houghton, 2000.

Essen (pop. 626,973), a city in western Germany, is in a major industrial region called the Ruhr (see Germany [political map]). The city is the home of the Krupp steelworks company, which was a major weapons manufacturer during World War I (1914-1918) and World War II (1939-1945). Other economic activity includes coal and electric power production, transportation, and commerce. Essen's landmarks include a cathedral that dates from the 800's; and Borbeck Castle, built in the 1200's.

Essen dates from the 800's, when it was the site of a convent. It became industrialized in the 1800's. Allied bombing raids during World War II destroyed much of Essen. But the city has been rebuilt. Peter H. Merkl

Essenes, *EHS eenz* or *eh SEENZ,* were members of a Jewish sect living in Palestine from about 150 B.C. to A.D. 68. They numbered about 4,000 and had a communal life. Essenes were *ascetics,* and tried to avoid contamination by worldly impurity (see **Asceticism**). According to the Jewish historian Josephus, the Essenes believed in the immortality of the soul, but rejected the idea of the resurrection of the body. They apparently objected to animal sacrifices. In the late 1940's and the 1950's, the remains of a settlement and several jars of scrolls were found at and around Khirbat Qumran near the Dead Sea. Many of these scrolls, which include the oldest Biblical manuscripts yet found, probably belonged to a group of Essenes. See **Dead Sea Scrolls.** Gary G. Porton

Estate is a legal term that refers to a person's total property. The term formerly referred mainly to a person's land. But today the term is usually associated with the property a person owns at death. In the United States, the federal government levies an *estate tax* on estates above a certain size. The tax is based on the estate's value at the time of the owner's death. There are two main kinds of estates—*leasehold* and *freehold.*

A leasehold estate is property specified in a contract or a lease by which the owner agrees to let another person use the property. The lease specifies how the property may be used, how long the property may be used, and what rent will be given to the owner (see **Lease**). A lease may last for life, for many years, or for a shorter period of time. Some leases specify that they may be ended at will.

A freehold estate involves some degree of ownership. In the United States today, there are two principal kinds of freehold estates. One is the *life estate,* which gives the possessor an interest in the property only during his or her lifetime (see **Fee**). The other is the estate in *fee simple,* which represents absolute ownership. However, the use of an estate in fee simple is subject to zoning laws and other legal restrictions.

Another form of estate, known as an estate in *fee tail,* is an old kind of freehold estate. At one time, the owners of such an estate could not sell or dispose of it. They had to leave it to a specified descendant. In most U.S. states today, however, the fee tail estate has become equivalent to an estate in fee simple.

The term *estate* meant the same thing as *status* in the days of the feudal system. The king owned the land in his realm. Private landowners were his tenants. They agreed to certain terms. Their *estate,* or status, in connection with the land they held, was the whole set of conditions of their tenancy. William M. McGovern

See also **Dower; Escheat.**

Estates-General was a French representative assembly that met irregularly between 1302 and 1789. It consisted of the delegates of three groups called *estates.* The first estate was the clergy, the second the nobility, and the third the common people. The Estates-General came into being as French kings began to invite leaders from each of the three estates to meet and discuss financial matters. The assembly never won the power to make laws, nor did it ever establish itself permanently.

The Estates-General was summoned repeatedly in the late 1500's, during the Wars of Religion—a series of civil wars between French Catholics and Protestants. However, King Henry IV, who ruled from 1589 to 1610, never called the Estates. Under his son Louis XIII, the Estates met only once, in 1614. The Estates-General was not called again until May 1789, shortly before the start of the French Revolution. That year, the government was almost bankrupt, and King Louis XVI could borrow more money or raise taxes only by calling a meeting of the Estates-General.

The royal government, in response to popular pressure, asked the French people to elect delegates to the Estates-General and to prepare lists of grievances along with suggestions for reforms. The government granted the third estate, which represented more than 95 percent of the people, twice as many delegates as each of the other estates. However, the third estate also demanded that all delegates receive the right to vote individually, rather than each estate receiving one vote. The king and the first and second estates resisted this demand.

On June 17, 1789, the third estate declared itself the National Assembly of France. It was soon joined by representatives of the other two estates. On June 20, the members of the new Assembly found themselves locked out of their meeting room. They then met on an indoor tennis court and swore that they would not disband until they had written a constitution for France. This vow became known as the Oath of the Tennis Court. Eventually, King Louis realized that he had to accept popular pressure for change, and the National Assembly gained control of France. Maarten Ultee

See also **French Revolution.**

Estéban. See Estevanico.

Ester is any of an important group of *organic* (carbon-containing) compounds. Esters belong to a class of oily or fatty substances called *lipids.* Lipids occur widely in plant and animal cells. Like other lipids, esters do not dissolve in water.

Esters have the general formula RCOOR′, where R and R′ stand for groups of atoms that include carbon atoms. Esters form when alcohols react chemically with acids. For example, ethyl alcohol (C_2H_5OH) reacts with acetic acid (CH_3COOH) to form the ester ethyl acetate ($CH_3COOC_2H_5$) and water (H_2O).

Waxes are esters that act as a protective, waterproof coating on skin, feathers, and leaves. Esters called *phosphoglycerides* serve as "building blocks" of cell membranes. Fats are esters of an alcohol called *glycerol* and fatty acids. Much of *cholesterol*—a fatty substance found in animal tissues—consists of esters of fatty acids. Other esters give fragrance to flowers and flavor to fruits. *Menthyl acetate* is an ester found in peppermint oil. Esters are used to make *polyesters,* a group of materials that are commonly used in fabrics. Roger D. Barry

Estevanico, *ehs tay vahn EE koh* (1500?-1539), also called *Estéban,* was a black slave from Morocco who became one of the first explorers of the Southwestern United States. His tales of the fabled Seven Cities of Cíbola led to the famous expedition of Francisco Coronado in 1540. See **Cíbola, Seven Cities of.**

Estevanico was a servant of an explorer on an expedition that landed at Tampa Bay, Florida, in 1528. Some of the group, including Estevanico and the Spanish explorer álvar Núñez Cabeza de Vaca, eventually reached what is now Texas. Indians there told Estevanico about the seven cities. They said the cities were built of gold.

Years later, in 1539, Estevanico became a guide on an expedition to the Southwest. He explored ahead into what are now Arizona and New Mexico. He reached Cíbola, where the Zuñi Indians killed him. Later, Coronado found that Cíbola consisted of Zuñi pueblos that shone like gold from afar. Edgar Allan Toppin

Esther, Book of, a book of the Bible, tells the story of Esther, a young Jewish woman, during the reign of Persian King Ahasuerus. The king selects the attractive Esther as his queen. Haman, the wicked prime minister, persuades the king to issue an order condemning all Jews to death. With the advice of her guardian, Mordecai, Esther persuades Ahasuerus to issue another order letting the Jews defend themselves on the day Haman's plan was to take place. Thus, Esther saved her people.

The Book of Esther was written during the period from 400 to 200 B.C. and deals with the theme of Jewish survival in the face of hardship. Each February or March, Jews celebrate their deliverance from the evil Haman in a joyous festival called Purim (see **Purim**).

There are also 107 verses not included in the Biblical book called Additions to the Book of Esther. They were composed and inserted into various points in the story about 100 B.C. The Additions are now part of a collection of religious writings called the Apocrypha. The verses are filled with a sense of devotion and prayer in contrast with the Book of Esther, which omits any reference to God and religious practices. Eric M. Meyers

Esthetics. See **Aesthetics.**

Estivation, *EHS tuh VAY shuhn,* is a dormant state that occurs in the life of some animals during hot, dry periods. The word is also spelled *aestivation.* Animals that estivate are protected from dryness in much the same way as those that hibernate are protected from cold. When an animal estivates, its breathing, heartbeat, and other body processes slow down. This reduction in activity decreases the need for water. The animal can thus survive hot, dry periods in which it otherwise might die.

Many amphibians and reptiles estivate, as do some insects, snails, and fish. Fish that estivate live in ponds and streams that evaporate during the dry season. Some estivators, including various kinds of frogs, lungfish, and salamanders, form a cocoon just before entering estivation. The cocoon helps prevent water loss from the skin. The animal awakens from estivation after the dry season and emerges from its cocoon. Larry L. Wolf

See also **Hibernation; Lungfish.**

Estonia, *eh STOH nee uh,* is a country on the Baltic Sea in northeastern Europe. The country's name in Estonian, the official language, is *Eesti Vabariik* (Republic of Estonia). Tallinn is Estonia's capital and largest city.

Through the centuries, Germans, Danes, Swedes, Poles, and Russians controlled Estonia, but Estonians continued to foster their own culture and language. The country was independent from 1918 until 1940, when the Soviet Union occupied it and made it one of the 15 Soviet republics. Estonia regained its independence in 1991.

Government. Estonia has a parliamentary democracy. The parliament has 101 members, elected by the people to a four-year term. The president, the head of state, is chosen by the parliament for a five-year term. The prime minister, recommended by the president and approved by the parliament, heads government operations.

Tass from Sovfoto

Tallinn, the capital of Estonia, has many beautiful churches, castles, and other structures that were built from the 1200's to the 1500's. The city lies on Estonia's northern coast.

Symbols of Estonia. Estonia's flag has three horizontal stripes. The blue stripe at the top of the flag represents the sky. The middle stripe of black stands for the land. The white stripe at the bottom symbolizes hope in the future. The Estonian coat of arms features three blue lions on a golden shield.

People. About 60 percent of the population are Estonians, a people related to the Finns. Most of the others are Russians. The population also includes small groups

Facts in brief

Capital: Tallinn.
Official language: Estonian.
Official name: Eesti Vabariik (Republic of Estonia).
Area: 17,413 mi^2 (45,100 km^2). *Greatest distances*—north-south, 150 mi (240 km); east-west, 230 mi (370 km). *Coastline*—481 mi (774 km).
Elevation: *Highest*—Munamagi, 1,043 ft (318 m). *Lowest*—sea level along the coast.
Population: *Estimated 2002 population*—1,368,000; density, 79 per mi^2 (30 per km^2); distribution, 69 percent urban, 31 percent rural. *1989 census*—1,565,662.
Chief products: *Agriculture*—barley, beef cattle, butter, chickens, eggs, hogs, milk, rye. *Manufacturing*—agricultural machinery, petrochemicals, processed foods, textiles.
Money: *Basic unit*—kroon. One hundred cents equal one kroon.

of Belarusians, Finns, and Ukrainians. The official language is Estonian, which is closely related to Finnish.

Most Estonians are urban dwellers and live in apartments in cities or towns. Many Estonians have colorful traditional costumes, which they wear on festive occasions. Folk songs have a long tradition in Estonia. A song festival is held every five years in Tallinn. It attracts thousands of singers and hundreds of thousands of visitors.

About 80 percent of the people are Lutherans. Most others belong to one of the Eastern Orthodox churches.

Estonia has seven colleges and universities. The oldest and best known is Tartu University, founded in 1632.

Land and climate. Estonia consists chiefly of a low plain. Farmland covers about 40 percent of the country, forests 30 percent, and swamps 20 percent. Lake Peipus and the Narva River form much of the eastern boundary.

Estonia, Latvia, and Lithuania are often called the Baltic States. Estonia has a total of 481 miles (774 kilometers) of coastline on the Baltic Sea, the Gulf of Finland, and the Gulf of Riga. The sandy western coast is a favorite resort area. About a tenth of Estonia consists of Baltic islands, the largest of which is Saaremaa Island.

Estonia has a surprisingly mild climate for an area so far north. Sea winds help keep the weather from becoming very cold or hot. Temperatures average from about 19 to 28 °F (−7 to −2 °C) in January to 61 to 64 °F (16 to 18 °C) in July. Estonia receives an average of 19 to 23 inches (48 to 58 centimeters) of rain annually.

Economy. Service industries employ more than half of Estonia's workers. The main service industries are wholesale and retail trade, transportation and communication, education, and health care and social work.

Manufacturing employs about a fourth of the workers. Estonia's manufactured products include agricultural machinery, chemical fertilizer, construction materials, processed foods, and textiles. Tallinn is an important center for fashion and design.

Oil shale is the country's most important mineral resource. It is used extensively as fuel for electrical power plants. It is also refined into petrochemicals.

François Gohier, Explorer

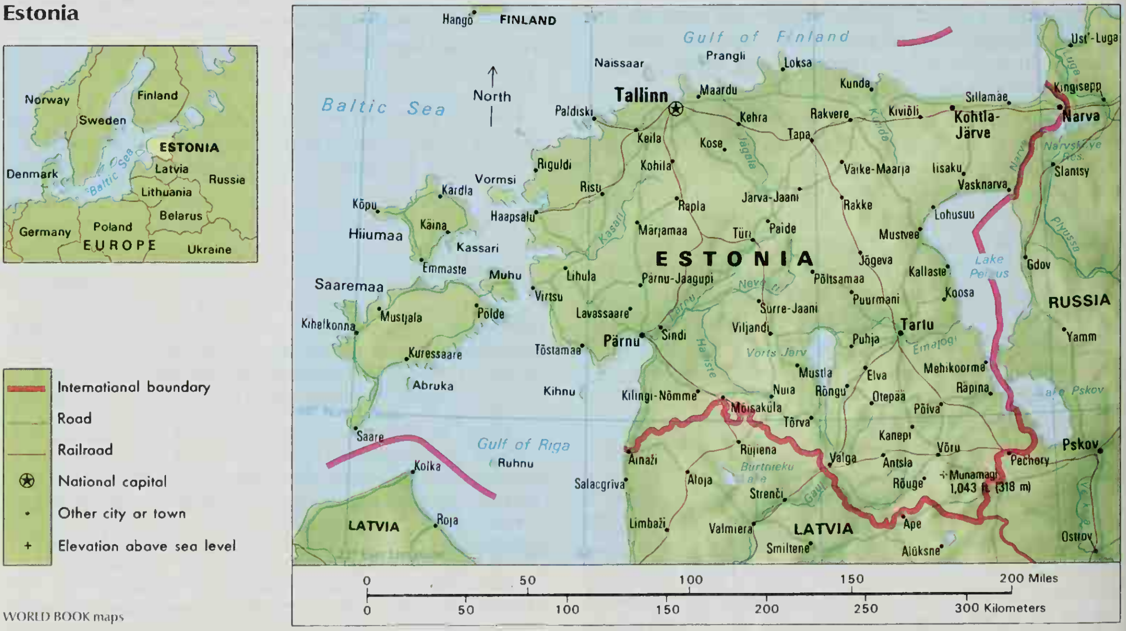
Traditional Estonian costumes are bright and colorful. The Estonian woman shown here is wearing a costume that includes an embroidered blouse and hat.

Estonia's chief agricultural products include barley, beef cattle, butter, chickens, eggs, hogs, milk, potatoes, and rye. Commercial fishing is also important.

History. People lived in what is now Estonia by 7000 B.C. The ancestors of the Estonians settled there several thousand years ago. They formed several independent states headed by elected elders.

Early rulers. During the early 1200's, the Teutonic Knights, an organization of German crusaders, con-

Estonia



WORLD BOOK maps

Estonians celebrated independence in September 1991, when the Soviet Union recognized Estonia as an independent nation. Estonia had been part of the Soviet Union since 1940, when the Soviets forcibly made it a Soviet republic.

verted the Estonians to Christianity by force (see **Teutonic Knights**). They took control of southern Estonia, and Danish forces conquered the north. The Danes sold their Estonian holdings to the Teutonic Knights in 1346.

By the 1500's, German nobles owned much of Estonia's land and controlled thousands of Estonian *serfs.* Serfs worked on the estates of the nobles. In 1561, Sweden took over northern Estonia, and Poland conquered the southern part of the country. Sweden controlled all of Estonia from 1625 to 1721, when the area fell to Russia. But German nobles kept estates there until 1919.

The serfs were freed in 1816, but most of the land remained in the hands of German nobles. In 1868, former serfs gained the right to buy land. Some became successful landowners and educated their children well. Others found industrial employment in cities.

Independence. A national revival begun in the mid-1800's led to the establishment of Estonia as an independent country. Estonia proclaimed its independence on Feb. 24, 1918. Russia recognized Estonia's independence in 1920. The Estonian Constitution established a democratic form of government. In 1919, the government took over the country's large estates and began distributing the land to thousands of Estonian citizens.

Soviet rule. The Soviet Union was formed in 1922 under Russia's leadership. In 1939, the Soviet Union and Germany agreed secretly to take over a number of eastern European countries between themselves. The Soviet Union established military bases in Estonia. Soviet forces occupied Estonia in June 1940. In August, the Soviets forcibly made Estonia part of the Soviet Union. Germany occupied Estonia in 1941, during World War II, but the Soviet Union regained control of Estonia in 1944.

Estonia went through great social and economic changes under Soviet rule. At the time of the Soviet take-over in 1940, Estonians made up about 90 percent of the country's population. When Estonia regained independence in 1991, Estonians made up about 60 percent of the population. Most Estonians opposed Soviet rule, and in 1941, before the German occupation, the Soviet government deported tens of thousands of Estonians to Siberia. About 100,000 Estonians fled to Western countries after the Soviet take-over. Hundreds of thousands of Russians settled in Estonia during Soviet rule.

Before Estonia became a Soviet republic, almost two-thirds of the Estonians farmed and lived in rural villages. But during Soviet rule, many people moved to the cities to find industrial jobs. The Soviets prohibited private factories and farms, and they established government-controlled enterprises. They created economic plans that emphasized industrial growth. Thus, Estonia experienced much industrial development. Although its economy was advanced by Soviet standards, there were widespread complaints about the shortages and poor quality of goods and services. Economic development brought many Soviet immigrants to work in Estonia. Industrial pollution became a major problem.

Resistance to Soviet rule. After World War II ended in 1945, movements against Soviet control appeared periodically. A strong guerrilla resistance against the Soviets lasted for several years after the war. But in 1949, many Estonians were deported to Siberia. A movement to promote human rights began in the 1960's. During the late 1980's, a new wave of Estonian nationalism appeared. It was fueled in part by Soviet leader Mikhail Gorbachev's call for greater openness of expression in the Soviet Union. Most Estonians demanded greater control over their government and economy. Many demanded complete independence from the Soviet Union.

Independence regained. In 1990, the Estonian parliament declared the 1940 Soviet annexation illegal and Soviet rule in Estonia invalid. The parliament called for the restoration of Estonian independence through a gradual separation from the Soviet Union. The Soviet Union called the parliament's action illegal.

In August 1991, several conservative Communist officials failed in an attempt to overthrow Gorbachev and take over the Soviet government. During the upheaval that followed, Estonia declared immediate independence. In September, the Soviet Union recognized Estonia's independence. In December, most of the republics formed an association called the Commonwealth of Independent States. Estonia declined to join, however, because it feared that Russia would control the group. On December 25, the Soviet Union was dissolved.

After becoming independent, Estonia moved forward with economic reform and reduced government control of most economic activities. By the mid-1990's, most businesses had become privately owned. Independent Estonia has sought to strengthen its ties with western Europe and to reduce Russian influence over its affairs. Estonia has worked toward membership in both the European Union and the North Atlantic Treaty Organization. Jaroslaw Bilocerkowycz

See also **Baltic States; Lake Peipus; Tallinn; Tartu.**

Estrogen, *EHS truh juhn,* is any of a group of chemically similar hormones that cause the growth and development of female sexual characteristics in human beings and other animals. Estrogens also influence the female reproductive cycle. Of several forms produced in a woman's body, *estradiol* is the strongest.

During a girl's preteen or early teen-age years, her ovaries begin to secrete increasing amounts of estrogens into the bloodstream. Estrogens cause the girl to develop breasts and rounded hips and cause the genital organs to enlarge and mature. Estrogens also stimulate the lining of the uterus to thicken. The hormone *progesterone* limits this growth. The uterine lining is shed during menstruation each month. The amount of estrogens secreted by the ovaries changes during the menstrual cycle. As the woman grows older, her ovaries secrete smaller amounts of estrogens. After the level of estrogens in the blood becomes too low to stimulate the uterine lining, menstruation no longer occurs. The woman is then said to have reached *menopause.*

In both women and men, small amounts of estrogens are produced in fat tissue, muscles, and many other parts of the body. In males, the *testes* (sex organs) also produce estrogens. The function of estrogens in the male is unclear.

The drug industry makes synthetic estrogens for use in birth control pills and for certain medical therapy. Use of large amounts of synthetic estrogens may harm some patients. Using birth control pills has been associated in some women with blood clots, high blood pressure, and diabetes. Women who take estrogen without progesterone are at higher risk for cancer of the *endometrium* (inner lining of the uterus). After menopause, many women require estrogen treatment to prevent loss of calcium from bones, to maintain a healthy vaginal lining, and to lower risk of heart disease. Such treatment is safe at properly prescribed dosages. Mona M. Shangold

Related articles in *World Book* include:

DES	Hormone replacement therapy	Progesterone
Hormone (Growth and sex hormones)	Menopause	Steroid
	Menstruation	Tamoxifen

Estrous cycle, *EHS truhs,* is the process that prepares the females of most species of mammals for mating and bearing young. It is also called the *breeding cycle.* Among many mammals, the estrous cycle occurs during a certain period, called the *breeding season.* The cycle is timed so that the young are born at the time of year when they have the best chance of survival.

During the estrous cycle, a period called *estrus,* or *heat,* occurs. The female is sexually excited throughout estrus and, among most species of mammals, will mate only during this period. The length of both the estrous cycle and estrus varies among the species. In most rats, the cycle lasts about 4 days, and estrus lasts about 14 hours. Among most breeds of dogs, the cycle lasts about six months and estrus lasts about three weeks.

Some mammals, including human beings and apes, do not have an estrous cycle. The females of these species have a *menstrual cycle,* which prepares them to bear young (see **Menstruation**). George B. Johnson

See also **Mammal** (How mammals reproduce).

Estuary is a coastal river valley flooded by an ocean. Most estuaries are funnel-shaped, with the wide end toward the sea. Chesapeake Bay on the Atlantic Coast is an estuary in the United States. The Rio de la Plata is a major estuary on the Atlantic in South America. Estuaries in Europe include the Gironde in France and the Humber, Severn, and Thames estuaries in the United Kingdom.

Most estuaries formed as the seas rose during the past 11,500 years. The water level rose because of the melting of vast ice sheets that had accumulated during the most recent ice age.

Within an estuary, currents created by the tides mix the salty seawater with the fresh water of the river. Where those currents are weak, little mixing occurs. Because the seawater is salty, it is denser than the river water. Therefore, the river water overlies the seawater, and there are large differences in *salinity* (saltiness). But where the currents are strong, much mixing occurs, and so the salinity is the same throughout the estuary.

The river erodes soil from the land and deposits much of it in the estuary as *sediment.* Waves and tidal currents can redistribute the sediment and deposit it around the edges of the estuary. The sediment can accumulate as *mudflats,* stretches of muddy land that are uncovered at low tide. David S. McArthur

See also **River** (The mouth of a river); **Tide.**

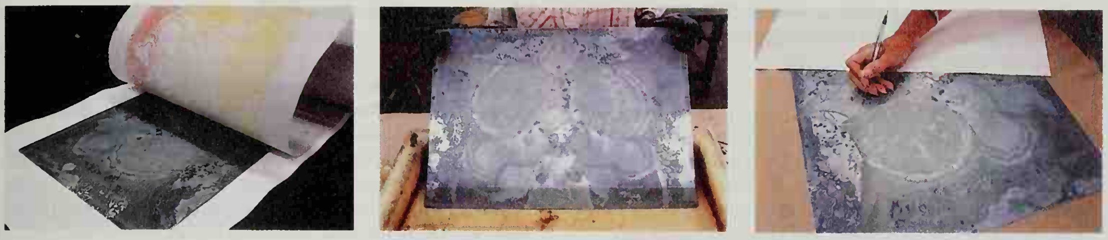
Etching is a process of creating a design on a metal plate with the use of acid. Etching has importance both in the fine arts and in commercial printing. This article discusses etching as a fine art. For information about etching in commercial printing, see **Photoengraving and photolithography.**

How etching works. Most plates used in etching are made of copper, zinc, or iron. First, the artist polishes the plate to remove any scratches. The plate is then covered with *ground,* an acid-resistant coating of beeswax, bitumen, and resin. After the ground dries, the artist draws a design or image into the ground using a sharp metal tool. The artist covers the edges and back of the plate with a tough, acid-resistant varnish and places the plate in an acid bath. Hydrochloric acid is used for copper plates and nitric acid for iron and zinc plates.

The acid *etches* (eats away) the exposed areas of metal, creating indentations. The depth of an indentation determines the appearance of a line in the finished picture. To make lines and dots of different depth and size, the artist gives the plate several acid baths, varying the time the plate is bathed. Before the second and each successive bath, the artist uses ground or varnish to *stop out* (cover) areas of the plate having the desired depth.

After finishing the etching process, the artist removes the ground and varnish. The plate is warmed and covered with a layer of oily ink. The artist wipes the plate with a pad of coarse buckram cloth until a deposit of ink has been forced into the etched indentations. The artist then places the inked plate on a press. He or she puts a sheet of dampened paper on the plate and covers the paper and plate with felt blankets. The press's heavy rollers exert great pressure on the felt, pushing the paper into the ink-filled grooves. This causes the ink to transfer onto the paper, creating the finished print.

Artists can achieve special effects by various methods, such as the way they apply and wipe the ink and the type of paper they use. Various tones can be created by roughening the plate's surface so it holds different amounts of ink. To combine tonal areas with an etched



WORLD BOOK photos by Dan Miller

Making an etching. The artist draws a picture by cutting through an acid-resistant coating on a metal plate, *left.* Then, the plate is placed in an acid bath, *center.* The acid eats away the exposed metal, creating indentations. The artist forces ink into the indentations and runs the plate and a piece of paper through a press. The ink transfers onto the paper, *right,* creating the print.

line, artists use a method that is called *aquatint.*

History. Etching began in the early 1500's in western Europe. It became an independent, creative art form in the 1600's, especially through the work of the Dutch artist Rembrandt. Pablo Picasso ranks as perhaps the greatest etcher of the 1900's. Andrew J. Stasik, Jr.

See also **Rembrandt; Glass** (Etching).

Ethane, *EHTH ayn,* is an important industrial gas. It is obtained directly from natural gas or by refining petroleum. Its most important use is in preparing ethylene. Ethane is sometimes used as a fuel. Industries also prepare important organic compounds from it. Ethane is a colorless, odorless, flammable gas, slightly heavier than air. It is soluble in alcohol, but only slightly soluble in water. Ethane has the chemical formula C_2H_6, and is the second member of the *paraffin* series of hydrocarbons. See also **Ethylene; Hydrocarbon.** Geoffrey E. Dolbear

Ether, in chemistry, is a colorless, highly flammable liquid with a strong, sweet smell. Ether vapor causes unconsciousness when inhaled. For many years, physicians used ether as a general anesthetic during surgery. General anesthetics make patients unconscious and insensitive to pain. Ether was one of the first general anesthetics to be developed.

Credit for the first use of ether as a surgical anesthetic is given to Crawford W. Long, a Georgia doctor. Long used ether during surgery as early as 1842. However, ether anesthesia did not come into wide use until after 1846, when William T. G. Morton, a Boston dentist, first publicly demonstrated it at the Massachusetts General Hospital. For the next hundred years, ether served as the standard to which all other anesthetics were compared.

Ether's popularity declined during the mid-1900's, largely because of the increasing use of electrical equipment in the operating room. The concentrated ether vapor needed for anesthesia produced a danger of fire and explosions when used around electrical equipment. In addition, many patients took a long time to wake up from ether anesthesia, and they frequently experienced nausea and vomiting afterward. To avoid these problems, scientists developed halothane and other general anesthetics that are nonflammable and less irritating.

Today, ether is rarely used as an anesthetic. It does serve, however, as a solvent in the manufacture of perfumes, explosives, and many other products. Ether's chemical name is *ethyl ether* or *diethyl ether.* Its chemical formula is $(C_2H_5)_2O$. Edwin S. Munson

See also **Anesthesia; Halothane; Long, Crawford W.; Morton, William T. G.**

Ether, in physics, was once believed to be a substance that filled all space. By the late 1600's, some physicists believed that light traveled in waves. They knew that light could travel through artificially created vacuums and through the void of outer space. But they could not explain how light could travel without a *medium* (substance) to travel through. As a result, they assumed the presence of a *luminiferous* (light-carrying) ether, a substance that differed from all other matter. It could not be seen, felt, or weighed and was present in vacuums, outer space, and all matter. The ether was stationary, and the earth and other bodies in space moved through it.

In 1864, the British physicist James Clerk Maxwell correctly suggested that light waves are electromagnetic and travel as disturbances of an electromagnetic field. Therefore, they do not need a medium to travel through. But Maxwell and other physicists still believed in the existence of ether.

In 1887, two American scientists, Albert A. Michelson and Edward W. Morley, conducted an experiment to measure the speed of the earth relative to the ether. Their findings suggested that the earth did not move through ether. However, Hendrik A. Lorentz, a Dutch physicist, explained the finding by assuming that ether affected matter in a complicated way. In 1905, the German-born physicist Albert Einstein published his special theory of relativity, which shows how light behaves and does not rely on the existence of ether. Richard L. Hilt

See also **Light** (Early ideas about light); **Relativity** (Special relativity).

Etherege, Sir George (1634?-1691), was an English playwright. Etherege wrote *comedies of manners,* which were clever satires of upper-class society. He provided comic portraits of London society during the Restoration period (1660-1700) in *The Comical Revenge, or Love in a Tub* (1664) and *She Would if She Could* (1668). But his fame rests on his only other play, *The Man of Mode, or Sir Fopling Flutter* (1676). The play is full of witty dialogue and sparkling language. Sir Fopling Flutter, a pretentious fool, is one of the most popular characters in English comedy. Etherege also created brilliant comic figures in Dorimant, an attractive young man who wins the affections of all the women in the play, and Loveit, his aging and abandoned mistress. Little is known of Etherege's early life. He was probably born in England. See also **Drama** (European drama: 1660-1800).

Albert Wertheim

Ethics is a branch of philosophy that attempts to help us understand which ways of life are worth following

and which actions are right or wrong. Ethics addresses questions of right and wrong using reason rather than faith or tradition.

Ethical issues

Some ethical theories seem complicated, but they are simply attempts to settle issues that we all think about. Usually, we think about these issues because we find ourselves faced with a tough decision.

For example: Alice knows that her friend Max has been using a harmful drug. She has tried to persuade him to stop, but he does not listen. She has begun to wonder if she should tell someone what he is doing, someone with authority who might make him stop. To some people facing such a choice, it might seem obvious that one should inform on Max. To others, it would seem equally obvious that they should say nothing.

If Alice is like most people, though, she will have conflicting thoughts. If she tells somebody, she would be violating her friend's trust in her. Max never would have let her know his secret if he had thought she would use it to get him into trouble. On the other hand, it may be best for him if she tells what she knows so that he can be helped. Alice's choice is difficult because she has more than one idea about what she should do, and these ideas lead her in opposite directions. Some philosophers would say that these conflicts arise because some of the ideas she is considering do not really apply to the question of what she should do.

Ethics tries to introduce order into the way people think about life and action. Often this means replacing the vast confusion of everyday ideas with one general theory. Ethical theories aim to bring order into ordinary thinking by telling us which of our conflicting ideas apply to what we should do and which ones do not apply.

Ancient ethics

Before the year 1500, many ethical theorists were followers of the ancient Greek philosophers, especially Plato and Aristotle. These two influential thinkers brought order into thinking about ethical problems by defining the sort of life that is worth living and the sort of person who can live such a life. We can understand what such an admirable person would be like, Plato and Aristotle thought, by understanding the good character traits, or virtues, that such a person would possess.

Plato thought there are four virtues: (1) wisdom, (2) courage, (3) temperance, or self-control, and (4) justice. The most important of these is wisdom, which is knowledge of what is truly good. People who have wisdom and, as a result, know what is truly good will tend to do what is right. These people will act in their own true interest and be in harmony with themselves. This harmony is the basis of all justice. People who have justice, in Plato's view, will tend to have other virtues as well. Plato did not try to tell us, in a neat and easy formula, what is truly good. Instead, he wrote books in which he described the life and death of one man who, he believed, did understand goodness—his teacher Socrates. See **Plato** (Ethics).

Aristotle, Plato's most distinguished student, had views that were similar but more complicated. Aristotle disliked oversimplification. Although he agreed with Plato's four virtues, he considered other traits to be important also. These traits included friendliness, generosity, gentleness, truthfulness, and wit.

Like Plato, Aristotle thought there is one trait that is the source of all the other virtues. He called it *phronesis,* meaning *prudence* or *good judgment.* Prudence is the ability to know what we should do by figuring out which course of action would lead to a good life.

Aristotle tells us much about what the good life is like. He says that it involves such things as having friends, acting justly, and participating in community affairs. However, like Plato, Aristotle did not specify which courses of action are right and which ones are wrong. People who are properly brought up and who make full use of their own minds will, he thought, usually see the right course and take it. See **Aristotle** (Ethics and politics).

Limitations of ancient ethics. Neither Plato nor Aristotle seems to offer help to people who, like Alice, face a tough decision and do not find the solution to be obvious. Perhaps in ancient Greece people faced fewer critical decisions in which clashing ideas pulled in opposite directions. Perhaps when the ancient thinkers developed their systems of ethics, such dilemmas seemed unusual and not important for discussion. Even in a complex society like ours, with all of its conflicting traditions and theories, most ethical decisions do not present us with such dilemmas.

For whatever reason, ancient ethics did not try to provide rules to guide us in making difficult choices. Modern ethics—beginning about 1500—does, on the contrary, try to provide such rules. Ancient ethics is a theory of normal life, while modern ethics is a theory of life in crisis. Modern ethics aims to help us sort out the conflicting reasons for different courses of action. Modern ethics tries to help us decide which reasons are important or fundamental and which are less important or not valid at all.

Modern ethics

When people face a critical choice like Alice's and hesitate between different courses of action, they think of reasons for the different things they might do. Modern thinkers have observed that the reasons people produce in such situations can be sorted into different categories. There are considerations of *benefits* and considerations of *obligations.* On one hand, Alice may think she has an obligation to Max to keep quiet about what he does. On the other hand, she may think he might benefit if she violates this obligation by speaking up. In this case, as in others, considering one's obligations may lead to different conclusions than considering what is beneficial to people. A person who always takes obligations seriously will make different decisions than a person who is committed to doing what is most beneficial to people. After hundreds of years of thinking about conflicts among moral ideas, theorists have reached at least one conclusion. This conclusion is that it is difficult to give equal importance to both obligations and benefits.

Modern ethical theory is roughly divided into two schools of thought: (1) *deontology* and (2) *teleology.* Deontology holds that what really matters, ethically, is what your obligations are. Teleology claims that what really

matters is which actions or policies would be most beneficial to people.

Kant. The greatest of the deontologists was Immanuel Kant, a German philosopher of the 1700's. He believed that the only test of whether a decision is right or wrong is whether it could be applied to everyone. Would it be all right for everyone to do what you are doing? If not, your decision is wrong. It would be wrong, for example, to make a promise with the intention of breaking it because if everyone did that, no one would believe anyone's promises. As a result, no one would make promises at all.

Kant thought that the difference between right and wrong is simply a matter of consistency: can you apply the same standard to others that you apply to yourself? You must ask if it would be acceptable if everyone were to act in the way that you propose to act. Using this test, Kant would probably say that Alice should inform the authorities about Max's drug use. To Kant, whether a person's decisions are useful, whether they bring about desirable results for oneself or anyone else, is not ethically important. See **Kant, Immanuel.**

Bentham and Mill. Arguing against Kant, teleologists have often pointed out that most moral rules are actually useful or beneficial. Rules against murder and theft serve to protect our interests. If there were no such rules, we would be faced with a constant threat of violent injury and death.

Moral rules protect us from misery and chaos, and it is hard to imagine anything more useful than that. Teleologists have asked what followers of Kant would say if a moral rule that they believe in was found to make people unhappy and do no good at all. They would immediately decide that the rule was a bad one. The reason for this, teleologists say, is that deontologists are like everyone else. Despite their theories, what matters in the end is what is beneficial or useful.

The most influential teleologists are the *utilitarians,* who include English philosophers Jeremy Bentham in the 1700's and John Stuart Mill in the 1800's. Utilitarians claim that the test of whether a policy or action is right is not whether it brings happiness to a particular individual, but whether it increases happiness for society as a whole. We should have rules against murder and theft, though they frustrate murderers and thieves, because most people are happier with such rules.

Mill argued that the code of rules that is best for humanity is one that prevents people from harming one another but otherwise lets them do what they want. People are happiest if they develop their ability to make choices and learn from their mistakes, provided they injure no one but themselves. Mill might tell Alice that she should think again about how beneficial it would be for Max if she were to inform on him. Being forced to quit drugs when he did not want to might cause more harm than good. According to Mill, we only reach full potential for happiness if society and government allow individuals to pursue their own experiments in living.

On the other hand, Kant's followers have asked what Mill would think of a system ruled by masterminds. These superior beings would persuade people to want what was best for them and thus would leave them unable to make their own choices. Of course, Mill would find such a system horrifying. But this shows, they say, that even for Mill there is something more important than satisfaction or happiness. That something is the dignity people have as rational beings, who are able to grasp moral law and make decisions based on it.

Nietzsche. Most modern ethical theorists have been either deontologists or teleologists, but some have criticized both of these positions. The most famous of these critics was the German philosopher Friedrich Nietzsche, who lived in the 1800's. Nietzsche thought that the ideas of the ancient Greeks were closer to the truth than those of the moderns. He believed that the problem the deontologists and teleologists argued about—the problem of which actions are right and which are wrong—cannot be solved and is not really that important. Different nations and cultures make up their own ethical rules to suit their own unique circumstances. According to Nietzsche, what is held to be right and good in one culture or historical period could be considered bad or evil in another culture or historical period.

Like Plato and Aristotle, Nietzsche thought that human beings should concern themselves with attaining virtue rather than with the correctness of their particular actions. His notion of virtue, however, was different from theirs. For him, attaining virtue was essentially a matter of achieving more power, especially power over oneself. Virtue does not depend upon believing some rational notion of the good life. There is no such thing as *the* good life. There are only a "thousand and one goals" that different people pursue. It is not one's choice of goals that determines one's virtue. It is rather the power with which one pursues whatever goals one has chosen. See **Nietzsche, Friedrich.**

What can ethics do for us?

Faced with the great variety of ethical theories, people may still lack answers to such questions as "How should I live?" and "What should I do?" Such questions probably ask too much of ethics. Perhaps ethics can do no more than help us make our own ideas clearer, more rational, and more responsive to the realities of life. Ethical theory might not tell Alice what to do. But it might help her to think clearly and critically about her values, and to decide whether she needs to develop better ones. That is probably a process that never ends. Lester H. Hunt

Related articles in *World Book* include:

Aristotle (Ethics and politics)
Kant, Immanuel
Medical ethics
Moral education
Philosophy (Ethics)
Plato (Ethics)
Religion (A code of conduct)

Additional resources

Ethics and Values. 8 vols. Grolier, 1998.
Terkel, Susan N., and Duval, R. S., eds. *Encyclopedia of Ethics.* Facts on File, 1999.

Ethiopia, *ee thee OH pee uh,* is a country in northeastern Africa. Much of Ethiopia consists of rugged mountains and a high plateau. Addis Ababa is Ethiopia's capital and largest city.

The name *Ethiopia* comes from a Greek word meaning *burned faces.* The ancient Greeks used the word to mean lands south of Egypt—including modern Ethiopia—where people had darker skins than the Greeks or most Egyptians. Ethiopia was formerly called *Abyssinia,* a term derived from *Habashat,* the name given the people of northern Ethiopia by neighbors in the Red Sea region.

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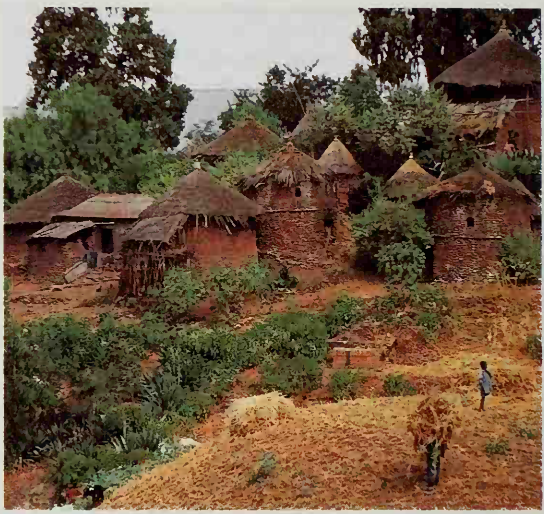
Addis Ababa, the capital and largest city of Ethiopia, has many modern buildings. An important Ethiopian economic center, the city also hosts many international African conferences.



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A typical Ethiopian village, such as this one in the north, consists of a number of round houses with thatched roofs. Most rural Ethiopians live in villages or isolated homesteads.

Ethiopia is one of the oldest nations. According to tradition, the first emperor of Ethiopia, Menelik I, was the son of the Biblical Queen of Sheba and King Solomon of Israel. Many later Ethiopian rulers claimed descent from Solomon and Sheba.

Droughts have occurred in Ethiopia from time to time. In the 1970's and 1980's, the country experienced several severe droughts. These droughts, combined with political unrest, led to the deaths of many people.

Government

National government of Ethiopia consists of a two-house legislature, a prime minister, and a president. The legislature, called the Federal Parliamentary Assembly, consists of the Council of the Federation and the Council of People's Representatives. The 117 members of the Council of the Federation are elected by Ethiopia's states. The people elect the 548 members of the Council of People's Representatives. The Council of People's Representatives chooses the prime minister, who heads the government. Both houses of the Assembly choose the president, who serves a mainly ceremonial role.

Local government. Ethiopia is divided into nine states and one metropolitan area, which includes Addis Ababa. The states were created on the basis of the ethnic groups living in them. Each state has its own parliamentary assembly chosen through local elections.

Courts. The Supreme Court is Ethiopia's highest court. It hears appeals from the High Court, the second highest court. Local peasants' and urban dwellers' associations act as courts for minor civil and criminal cases.

Armed forces. Ethiopia maintains an army and an air force of about 100,000 people. Members of the armed forces must be at least 18 years of age.

People

Ancestry and languages. The government classifies Ethiopians into groups based on the main language they speak. About 80 languages are spoken in Ethiopia. The Oromo make up the largest ethnic and language group. The Oromo speak a Cushitic language called Oromifa or Oromo. They live in the central and southern parts of the country. The Amhara and Tigrayan peoples of the northern plateau speak Amharic—the nation's official language—and Tigrinya, respectively. These Semitic languages belong to the Afro-Asian language family, which also includes Arabic and Hebrew. Other important ethnic and language groups in Ethiopia include the Somali, who live in the southeast, and the Afar, who live in the east and northeast. A number of smaller groups live in the southwest and along the border with Sudan. Many Ethiopians speak more than one language, including English and other Ethiopian and European languages.

Ge'ez (also called Ethiopic) is an ancient Ethiopian language. In the past, all Ethiopian Bibles were written in it. Ge'ez is still used in ceremonies of the Ethiopian Orthodox Church.

Facts in brief

Capital: Addis Ababa.
Official language: Amharic.
Official name: Federal Democratic Republic of Ethiopia.
Area: 426,373 mi^2 (1,104,300 km^2). *Greatest distances*—north-south, 800 mi (1,290 km); east-west, 1,035 mi (1,666 km).
Elevation: *Highest*—Ras Dashen, 15,158 ft (4,620 m) above sea level. *Lowest*—Denakil Depression, 381 ft (116 m) below sea level.
Population: *Estimated 2002 population*—65,579,000; density, 154 per mi^2 (59 per km^2); distribution, 85 percent rural, 15 percent urban. *1994 census*—49,218,178.
Chief products: *Agriculture*—coffee, corn, oilseeds, sorghum, sugar cane, teff, wheat. *Manufacturing*—cement, processed food, shoes, textiles.
National anthem: "Whedefit Gesgeshi Woude Henate Ethiopia" ("March Forward, Dear Mother Ethiopia, Bloom and Flourish").
Flag: The flag has three horizontal stripes—green, yellow, and red (from top to bottom). The country's coat of arms appears in the center. It has a yellow star design on a round blue field. See Flag (picture: Flags of Africa).
Money: *Basic unit*—birr. One hundred cents equal one birr.

Way of life. Most Ethiopians live in rural areas as either farmers or livestock herders. Many farmers use an ancient wooden plow called a *maresha* and a pair of oxen to plow their fields. They grow various cereal crops, including barley, corn, wheat, and a tiny local grain called *teff.* Livestock herders raise camels, cattle, goats, and sheep, and travel from place to place to find food for their animals. Ethiopians in cities and towns work for the government, hold jobs in various businesses and industries, or run shops.

Poverty in Ethiopia is widespread. Each year, many Ethiopian men and women move to towns and cities to seek jobs and a better life. Medical care, electric power, schools, and clean water supplies are part of what attracts rural Ethiopians to cities.

Styles of houses vary widely in Ethiopia. Many houses in rural areas are round with walls constructed of wooden poles and mud plaster. These houses have roofs of thatch or corrugated iron. In Tigray areas, houses often are rectangular and made of stone. Addis Ababa and other cities have tall office buildings, multistory apartment houses, large villas, and mixed neighborhoods of stone, brick, mud, and cement houses.

In rural areas, many men and women wear a one-piece white cotton cloth called a *shamma.* Men wear a shamma over a cotton shirt, and women wear it over a cotton dress. In towns and cities, many people wear clothing similar to that worn in Europe and North America. In southern Ethiopia, some people wear traditional clothing made of leather or a colorful cloth used as a shawl and a waist wrap.

Ethiopians eat a wide variety of foods based on a diet of *injera.* This large flat bread is made of fermented flour from teff or other grains. In addition, Ethiopians eat barley, corn, or wheat, which are roasted or boiled. Ethiopians in some areas eat a bread made from the root of *ensete,* a plant that resembles a banana tree. Popular beverages include beer, coffee, tea, and thin yogurt.

Favorite sports in Ethiopia include soccer, volleyball, and *genna,* a game similar to field hockey. Ethiopians also enjoy playing card games, and a local kind of chess and other board games. Holidays include special celebrations from both the Christian and the Islamic faiths.

Religion. Most Ethiopians are either Christians or Muslims. About 40 percent of the people belong to the Ethiopian Orthodox Church, a Christian faith related to Coptic, Greek, and Russian Orthodox churches. A small percentage in the south and west practice local religions.

Until the 1980's, a small group of Jewish Ethiopians called the Falashas or Beta Israel lived in the northeast highlands and practiced an old form of Judaism. In the mid-1980's and in 1991, these people left Ethiopia, taking

Ethiopia

International boundary
Road
Railroad
Seasonal stream
Swamp
National capital
Other city or town
Elevation above sea level

WORLD BOOK maps

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The spectacular Tissisat Falls is formed by waters of the Blue Nile River. The falls is on the Ethiopian Plateau, about 20 miles (32 kilometers) southeast of Lake Tana.

up citizenship in the Jewish state of Israel. However, a number of Jews known as Falash Mura remained in Ethiopia. These people are descendants of Jews who had converted to Christianity in the mid-1900's, many to avoid persecution. Beginning in the late 1990's, the government of Israel began to allow some Falash Mura to immigrate to Israel.

Education. Ethiopian children are not required by law to attend school. About 45 percent of the children attend elementary school, but less than 15 percent attend high school. The main national university is Addis Ababa University, which has several branches.

The arts. Much of the country's art is related to the Ethiopian Orthodox religion. In the past, many artists painted church walls with Biblical scenes and pictures of saints. Artists also illustrated religious manuscripts with elaborate decorations. Writers created religious poetry and other sacred works in the Ge'ez language.

Since the early 1900's, Ethiopian writers have produced novels, plays, and poetry in Amharic and other modern Ethiopian languages. Modern artists have created murals, paintings, and stained-glass windows that incorporate Western styles.

Land and climate

Ethiopia has an area of about 426,000 square miles (1,104,000 square kilometers). The Ethiopian Plateau covers much of the western and central parts of the country. Lowlands surround the plateau.

The Ethiopian Plateau spreads out over about two-thirds of the country. It lies between 6,000 and 10,000 feet (1,800 and 3,000 meters) above sea level. Most of Ethiopia's people live on the plateau, which has the country's best agricultural land. Most of the plateau receives more than 40 inches (102 centimeters) of rain annually. Average temperatures on the plateau range from about 72 °F (22 °C) in areas below 8,000 feet (2,400 meters) to less than 60 °F (16 °C) at higher altitudes.

The Great Rift Valley, which runs north and south through eastern Africa, divides the plateau into two large sections. The sections are further divided by deep, spectacular river gorges and high mountain ranges. Ethiopia's highest mountain, Ras Dashen, rises 15,158 feet (4,620 meters) above sea level on the plateau.

The lowlands. The Ethiopian Plateau slopes downward in all directions toward lowland regions. Most of the lowland areas have an average temperature of about 80 °F (27 °C) and receive less than 20 inches (51 centimeters) of rain a year. The Denakil Depression in northeastern Ethiopia, which lies below sea level, is one of the hottest places in the world. Temperatures in the Denakil Depression sometimes rise above 120 °F (49 °C). The lowlands are thinly populated because of the hot, dry climate and because the soil is poor for farming.

Rivers and lakes. Ethiopia's chief rivers include the Awash, Baro, Blue Nile (called Abay in Ethiopia), Genale, Omo, and Wabe Shebele. Lake Tana, the country's largest lake, lies in the northwest. A series of lakes extends through southern Ethiopia along the Great Rift Valley. The lakes include Abaya and Ziway.

Animal life and vegetation. A wide variety of animals live in Ethiopia. Some of them live nowhere else. They include an antelope called the walia ibex and the Simien fox, also known as the Simien jackal or Ethiopian wolf. Coffee originated in the forests of southwest Ethiopia. Teff and several other types of crops also had their origins in the country. Forests cover part of the southwest. The most common tree in Ethiopia is the eucalyptus, which was imported from Australia in the 1890's.

Economy

Ethiopia has a developing economy. Agriculture is the chief economic activity. But many farmers struggle just to raise enough food for their families. Droughts occur from time to time and sometimes result in famine. Agriculture employs about 85 percent of the country's workers. About 5 percent of the workers have jobs in manufacturing, and about 10 percent in service industries, such as banking, government, insurance, and tourism. Mining and fishing are minor economic activities.

Agriculture. Most Ethiopian farmers produce goods chiefly for their own use. The main crops include wheat, corn, sorghum, and teff. Many farmers in the southwest grow coffee plants. Other crops grown for sale include oilseeds and sugar cane. Most farmers also raise cattle, goats, sheep, and chickens.

Farmers make use of only a small part of the land suitable for agriculture in Ethiopia. Improvements in farming equipment and methods, marketing, and transportation are needed to increase agricultural output.

Manufacturing. The production of textiles ranks as Ethiopia's chief manufacturing activity. Other products include cement, processed foods, and shoes.

International trade. Coffee, livestock, hides and skins, and oilseeds rank among Ethiopia's chief exports. Imports include chemicals, crude petroleum, and machinery. Ethiopia's chief trading partners include Germany, Italy, Japan, Saudi Arabia, and the United States.

Transportation and communication. Most of Ethiopia's roads are unpaved. The country has one rail-


Hulton Getty/Archive Photos

Haile Selassie I ruled Ethiopia as emperor beginning in 1930. He gave the country its first written constitution in 1931. His reign ended in 1974, when military leaders overthrew him.

road. It helps connect Addis Ababa with the port city of Djibouti, in the country also called Djibouti. An international airport operates at Addis Ababa. Much of Ethiopia's foreign trade takes place through Djibouti. Ethiopia also uses the Eritrean ports of Assab and Massawa.

There are about 3 million radios and about 40,000 television sets in Ethiopia. Several daily newspapers are published in Amharic, English, and Tigrinya.

History

Early days. Some of the oldest fossil fragments of human beings have been found in Ethiopia. They date from about 2 million years ago. By 500 B.C., two major groups, speakers of Semitic and Cushitic languages, inhabited the area. The plow was already the major agricultural tool by that time, and there is evidence that Ethiopians controlled water and used irrigation.

The Aksum Kingdom was the first important state in what is now Ethiopia. It was well established by the A.D. 200's. Its capital was the city of Aksum. The Aksum Kingdom gained much wealth through trade with Arabia, Egypt, Greece, India, Persia, and Rome. The Aksumites exported gold, ivory, and spices. Aksum reached its height of power in the 300's under King Ezana. He made Christianity the official religion of Aksum. In the late 600's, Aksum's power fell sharply after Muslims gained control of Arabia, the Red Sea, and the coast of northern Africa. The Muslims, religious enemies of Christian Aksum, put an end to the kingdom's foreign trade.

The Zagwé dynasty. In 1137, the Zagwé *dynasty* (series of rulers) rose to power on the Ethiopian Plateau. The Zagwé rulers had their capital at Roha—now called Lalibela. During the reign of the Zagwé emperors, 11 magnificent churches were carved out of solid rock at Roha. The churches still stand. In 1270, Yekuno Amlak overthrew the Zagwé dynasty. After the 1500's, the Ethiopian Empire broke up into a number of small kingdoms.

Menelik II, who became emperor in 1889, reunified the old Ethiopian Empire by gaining control of many of the small kingdoms. In 1896, at the Battle of Adwa, Menelik defeated an Italian army that had occupied a part of Ethiopia called Eritrea. This victory earned him much respect and helped increase his power in Ethiopia.

Under Menelik, Ethiopia engaged in its own colonial expansion and nearly doubled its territory to the south and east. Menelik made Addis Ababa the capital of Ethiopia and began the construction of a railway that, when completed, linked Addis Ababa to Djibouti. Menelik also established the first modern schools and hospitals in Ethiopia.

In 1913, Lij Iyasu, Menelik's grandson, became emperor of Ethiopia. Rumored to have converted to Islam, Lij Iyasu was removed from power in 1916 by Christian Ethiopians with the help of the United Kingdom, France, and Italy. These countries opposed Lij Iyasu because he sided against them in World War I (1914-1918). Zawditu, Menelik's daughter, then became empress of Ethiopia. She ruled with the help of Ras Tafari, the son of Menelik's cousin. Tafari was named heir to the throne.

Haile Selassie. Zawditu died in 1930. Tafari then became emperor and took the title Haile Selassie I. He continued Menelik's policy of modernizing Ethiopia. In 1931, he gave the country its first written constitution.

Italy invaded Ethiopia in 1935 in an attempt to expand its colonies in Africa. In 1936, the Italians conquered Addis Ababa, and Haile Selassie fled to the United Kingdom. Italian rule was harsh. However, many fine roads were built under Italian rule, providing a long-term benefit to Ethiopia. In 1941, during World War II, British troops helped the Ethiopians drive the Italians out of Ethiopia. Haile Selassie then returned to the throne.

Eritrea, a mountainous area along the Red Sea, had been captured by Italy in the 1880's. In 1952, Ethiopia regained control of the area. In 1961, Eritrean and Ethiopian nationalists debated whether Eritrea should be an independent nation or a federation with Ethiopia. The Ethiopian government rejected the call for Eritrean independence and annexed the area. Civil war broke out in Eritrea in 1962.

The Ogaden region of southeastern Ethiopia also became a trouble spot in the 1960's. The government of neighboring Somalia claimed the region, which Menelik had conquered in the 1890's. Many Somali people had always lived there, and they revolted against Ethiopian rule. In the late 1970's, Ethiopia and Somalia fought over the Ogaden region.

Military take-over. In the 1960's, many Ethiopians became dissatisfied with Haile Selassie's government. They demanded better living conditions for the poor and an end to government corruption. In 1972 and 1973, severe drought led to famine in the northeastern part of Ethiopia. Haile Selassie's critics claimed that the government ignored victims of the famine. In 1974, Ethiopian military leaders seized the government and removed Haile Selassie from power.

The military government, under Lieutenant Colonel Mengistu Haile-Mariam, adopted socialist policies and established close relations with the Soviet Union. In 1975, the government began large-scale land reform, breaking up the huge estates of the former nobility. The government claimed ownership of this land. But the military leaders also killed many of their Ethiopian opponents. In the late 1970's, people in the Tigray region in

the north called for independence from the central government.

In 1987, Ethiopia adopted a constitution that provided for a return to civilian government. A parliament was elected, but the country's military leaders still held power. Lieutenant Colonel Mengistu became president.

Recent developments. Ethiopia's government continued to face rebellions in the Eritrea and Tigray regions in the 1980's. In 1991, a rebel group consisting of Eritrean, Tigrayan, and other forces defeated President Mengistu and his army. In May 1991, rebels, chiefly from the province of Tigray, took control of the government. The rebel groups agreed that Eritrea would become an independent nation. Eritrea gained independence in 1993. At that time, however, part of the border between the two countries was not clearly defined. Ethiopia and Eritrea fought a bloody war over this disputed area from May 1998 to June 2000, when the two sides signed a cease-fire agreement. They signed a formal peace treaty in December 2000. The treaty included a provision that established a commission to identify the border between the two countries.

In 1994, Ethiopia adopted a new constitution. In 1995, the country held its first multiparty parliamentary elections. The Ethiopian People's Democratic Revolutionary Front, which had dominated the government since 1991, won the 1995 elections as well as ones held in 2000.

James C. McCann

Related articles in *World Book* include:

Addis Ababa	Great Rift Valley	Lake Tana
Aksum	Haile Selassie I	Menelik II
Clothing (picture: Traditional costumes)	Hamites	Prester John
Eritrea	Helmet	Semites
	Italo-Ethiopian War	

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Ethnic group is a group of people with characteristics in common that distinguish them from most other people of the same society. Members may have ties of ancestry, culture, language, nationality, or religion, or a combination of these things. Most ethnic groups are minority groups with at least some values or institutions that differ from those of the larger society. Since ancient times, ethnic groups have resulted from migrations, wars, slavery, changed political boundaries, and other significant movements of peoples.

In some countries, ethnic identification may affect both social standing and access to power. In Japan, for example, people of Korean ancestry have suffered discrimination at the hands of the Japanese.

In the United States, the term *ethnic group* refers especially to nationality groups that have immigrated to America since about 1840. These groups include Chinese, Dutch, Germans, Greeks, Irish, Italians, Japanese, Jews, Mexicans, and Poles. Other groups include African Americans, whose ancestors were brought to the United States as slaves, and American Indians.

Ethnic groups provide their members with a sense of belonging. They can bring variety and richness to a society by introducing their own ideas and ways of life. Some members of ethnic groups prefer to live with members of the same group. But ethnic groups that cling to their old values and customs can also threaten national unity. In many parts of the world, neighboring ethnic groups dislike and distrust one another.

The United States is one of the world's most ethnically mixed societies. Some social scientists call the nation a *melting pot,* meaning its different ethnic groups have joined to form a unified culture and have given up their ethnic ties. Others believe the country consists of many separate ethnic groups. Their view is called *ethnic pluralism.* Most social scientists believe that there has been considerable "melting" in the United States, but that the nation also reflects much pluralism. Thomas F. Pettigrew

See also the *People* section of the continent and country articles in ***World Book,*** such as **Africa** (People).

Ethnocentrism, *EHTH noh SEHN trihz uhm,* is the belief that one's own culture is the best and most natural. William Graham Sumner, an American sociologist, introduced the term in 1906. He defined ethnocentrism as "the tendency to view one's own group as the center of everything, and all others are scaled and rated with reference to it."

As a result of growing up within a culture, people come to view their society's ways as the normal and proper ways of thinking, feeling, and acting. Because of this, ethnocentrism probably cannot be avoided. It gives people a sense of belonging and pride, and a willingness to sacrifice for the good of the group. But ethnocentrism is harmful if carried to extremes. It may cause prejudice, automatic rejection of ideas from other cultures, and even persecution of other groups. Exposure to other cultures may lessen such reactions, but they can never be completely overcome.

Many social scientists consider ethnocentrism a problem in their work. A researcher's observations should be impartial. However, a tendency to judge other people by the standards of one's own group may distort these observations. James W. Vander Zanden

See also **Ethnic group; Minority group; Racism.**

Ethnography is a branch of anthropology that produces scientific descriptions of contemporary cultures. The term also refers to a written, photographic, or motion-picture report that provides such a description. An ethnography deals with one group of people or, at the most, several neighboring peoples.

Anthropologists compare ethnographies to determine similarities and differences in how human groups behave. Such comparative study is called *ethnology.* Ethnography and ethnology provide the basis for two chief branches of anthropology—*cultural anthropology* and *social anthropology.*

An anthropologist gathers information for an ethnography by doing *field work*—that is, by living with a group of people and studying their culture. The ethnographer studies the people's values, daily life, and social relationships. He or she obtains information in a variety of ways, including talking with the people and filming them.

Ethnography requires sensitivity and an ability to speak the language of the people being studied. An ethnographer must become involved with the people to understand their culture. At the same time, he or she must remain a detached, scientific observer.

Most ethnographers are trained in anthropology, but other scientists also do ethnographic research. Two

classic ethnographies are *Argonauts of the Western Pacific* (1922), by the Polish-born anthropologist Bronislaw Malinowski, and *The Nuer* (1940), by the British anthropologist E. E. Evans-Pritchard. Paul Bohannan

Ethnology. See Ethnography.

Ethology, *ih THAHL uh jee,* is the branch of zoology that deals with animal instincts. Ethologists study such instinctive behavior as courtship, mating, and care of young. They also study how animals communicate and how animals establish and defend their territories.

Ethologists seek to determine what causes instinctive behavior, how such behavior developed over millions of years, and how it helps a species survive. For each kind of animal studied, ethologists prepare an *ethogram,* a list that describes the known behavior patterns of the species. In the ethogram, they also try to specify conditions under which each instinctive act occurs. Ethologists have developed ethograms for various species of insects, fishes, birds, and mammals. Duane M. Rumbaugh

Related articles in *World Book* include:

Dominance	Lorenz, Konrad Z.	Tinbergen, Nikolaas
Frisch, Karl von	Morris, Desmond	
Instinct	Sociobiology	

Ethyl alcohol. See Alcohol.

Ethylene, *EHTH uh leen,* an organic gas, is one of the most important industrial chemicals. In the United States, the chemical industry uses about 33 billion pounds (15 billion kilograms) of ethylene each year.

The chemical industry uses ethylene to prepare compounds, such as ethylene oxide, polyethylene, ethyl alcohol, ethylbenzene, ethyl chloride, and ethylene dichloride. Ethylene oxide is used to make ethylene glycol (antifreeze). The plastics industry uses polyethylene. Plastics manufacturers also convert ethylbenzene to styrene, which is used for plastics and synthetic rubber. Ethylene is also used to help ripen fruit. Ethylene is prepared by heating ethane and propane to high temperatures in the presence of steam. Ethylene is also obtained as a by-product of petroleum refinery processes.

Ethylene is a colorless, flammable gas that has a faint, sweet odor. It is slightly lighter than air. Its chemical formula is C_2H_4, and it is the first member of the *olefin* series of aliphatic hydrocarbons. Ethylene mixed with air is explosive. Geoffrey E. Dolbear

Etiquette, *EHT uh keht,* is a code of behavior that helps people get along with one another. Some people think of it as a set of rigid rules concerning such subjects as the proper dress for a party, the organization of a wedding, or the setting of a dinner table. But etiquette deals with a much wider range of behavior—everything from being a guest to blowing your nose, riding an elevator to writing a letter.

Each culture has its own system of etiquette. Behavior considered proper in one culture may be considered improper in another. In Japan, for example, people take off their shoes before entering a house. In the United States, guests might be regarded as impolite if they removed their shoes. In general, this article discusses etiquette in Western society.

Etiquette also varies within a culture. People in large cities have customs that differ from those of residents of small towns. For example, in large U.S. cities, most people do not drop in on each other uninvited. In small U.S. towns, however, an occasional unannounced visit is considered friendly. Many cultural subgroups—such as teen-agers, politicians, or sports teammates—have their own rules to guide behavior, language, and dress within the group. Thus, a greeting considered appropriate between two surfers may be inappropriate for two judges.

A special form of etiquette called *protocol* is observed at social functions attended by government officials, military officers, foreign diplomats, and high-level professional people. For example, protocol specifies that such individuals be seated at dinner in a definite order according to their rank or position. Protocol also indicates the titles that should be used when speaking or writing to these people (see **Address, Forms of**).

Etiquette in daily life

Introduction etiquette. Proper etiquette requires that introductions be made whenever necessary. If someone you know joins your conversational group, you should introduce that person to the group. Further etiquette guidelines state that you first introduce a younger person to an older person, and a nonofficial person to an official person.

For example, "Mr. Jones, may I present my daughter Barbara Smith. Barbara, this is my boss, Mr. Anthony Jones." Or, "Congresswoman Warren, I would like to introduce Steven Strong, who works with me at the Acme Company. Steven, this is Congresswoman Jean Warren, who represents this district in Washington." When introducing someone, include some information about that person. This helps the people being introduced to engage in further conversation.

Always shake hands when you are introduced to someone. Look the person in the eyes and use a firm grip. If you are seated when a newcomer enters the room, stand up to be greeted or introduced.

Invitation etiquette. Invitations may be extended in the form of a written note, a printed or engraved card, a telephone call, or even an e-mail message. Your choice of form may depend on the size and formality of the event and the time available for organizing it. For example, a person might use the telephone to invite six friends to dinner. But for a wedding, a person might use printed or engraved invitations and mail them six weeks before the event.

It is important to reply promptly to any invitation sent to you. A guest should respond to an invitation by telephone or by mail within five days of receiving it. Replies to formal invitations, such as those for weddings, follow a prescribed format (see **Letter writing** [Formal invitations; Informal invitations]).

Dating etiquette. In the past, dating followed a set of specific rules. For example, the man chose the activities for the date and paid all the expenses. Today, the rules of dating etiquette are much more flexible. Women can ask out men, and many couples share the cost of the date and decide together what they will do.

Telephone etiquette. Courtesy is as important when speaking over the telephone as when talking face to face. A person should answer the phone with a pleasant "hello." When taking a message, write down the caller's full name and telephone number, as well as the time of the call. When using answering machines and *voice mail* answering systems, keep greetings and messages brief.

Additionally, the increased use of portable *cellular*

phones and *pagers* has generated new rules of etiquette. For instance, it is impolite to talk on a cellular phone while in a restaurant or motion-picture theater. Turn off your phone or pager when silence or respect is required, such as in a library or place of worship.

Internet etiquette. With the growing popularity of the Internet and e-mail in the 1990's, new rules of etiquette developed. Internet etiquette closely reflects the rules for mail and telephone interaction. For instance, e-mailers should be courteous when sending messages and prompt when responding. E-mailers should not send unwanted electronic files or chain letters. Always respect the customs and focus of any Internet *chat room* (specialized discussion forum) that you enter.

How etiquette develops and changes

The origins of etiquette. As prehistoric people began to interact with one another, they learned to behave in ways that made life easier and more pleasant. For example, as people learned to plant crops and farm, the ability to store food led to communal eating. Rituals developed for the preparation and sharing of meals which, over time, evolved into the table manners of today.

Early civilizations, such as ancient Greece and Rome, also developed rules for proper social conduct. Such rules became more formal during the Middle Ages, a period from about the A.D. 400's to the 1500's in Europe. During the Middle Ages, boys training to be knights learned a code of conduct called *chivalry.* According to this code, a knight was devoted to the Christian church and his country and treated women with great respect. Some aspects of chivalry, particularly the special treatment of women, became a traditional part of manners.

Much of today's formal etiquette originated in the French royal courts during the 1600's and 1700's. King Louis XIV drew up a daily list of events, giving time, place, and proper dress. It was posted in his palace at Versailles as an *étiquette,* a French word meaning *ticket,* to help the nobles know what to do. It brought order to court society, and other monarchs adopted the code of behavior for their own courts. In time, upper classes throughout the Western world adopted the code.

Etiquette today concerns itself less with rigid rules governing formal occasions, and more with everyday living. The goal is to help people of all lifestyles get along well with one another. Etiquette today is based on common sense and consideration of the other person.

Etiquette also changes and adapts along with changes in society. Prior to the mid-1960's, men were raised to treat women with special politeness. But since 1950, the roles of women have changed rapidly. What used to be considered the correct behavior—emphasizing male gallantry and chivalry—no longer has a place in the business world. When men and women work together, good manners decree that they help each other when help is needed, without any reference to a person's sex.

Books on etiquette

The first known guide to courteous behavior was written by Ptah-hotep, a government official in ancient Egypt. His work, *The Instruction of Ptah-hotep,* dates from about 2400 B.C. One of the earliest European etiquette books, *A Treatise on Courtesy,* was compiled by the German writer Thomasin von Zerclaere in about A.D. 1200. A hugely popular guide to manners, *On Civility in Children,* by the Dutch scholar Erasmus, appeared in 1530. It became required reading for young people throughout Europe for more than two centuries. The first established etiquette guide in the United States was *Etiquette* (1922), by the American author Emily Post (see **Post, Emily Price**). Alex J. Packer

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Etna, Mount. See Mount Etna.

Eton College, *EE tuhn,* is the largest and most famous of the group of English private secondary schools called *public schools.* The full name of Eton, a boys' school, is the King's College of Our Lady of Eton Beside Windsor. Many English statesmen, including 20 prime ministers, have graduated from Eton. The school is in the town of Eton, about 20 miles (32 kilometers) west of London.

More than 1,200 boys, from 12 through 18 years old, live and study at Eton College. Eton offers courses in such subjects as ancient history, divinity, Greek, Latin, modern languages, mathematics, and science. Each student is assigned a tutor who provides assistance and instruction outside of classes.

King Henry VI founded Eton in 1440 for 70 *Scholars* and up to 20 *Oppidans.* Scholars, most of whom were poor, received scholarships and lived in the college. Oppidans came from prosperous families and paid for their room and board in the town of Eton. Today, all students live at the college. P. A. McGinley

See also **England** (Education).

Etruscans, *ih TRUHS kuhnz,* were a people who lived in Etruria (present-day Tuscany, Umbria, and Latium) in Italy. Etruria extended from the Arno River in the north to the Tiber River in the south, and from the Apennine Mountains in the east to the Tyrrhenian Sea in the west. Most scholars today believe that the Etruscans migrated to Etruria about 800 B.C. from the east, probably by sea.

In Etruria, the Etruscans made near-slaves of the people who lived there. The Etruscans then spread north across the Apennines into the Po Valley and south across the Tiber River into Latium and Campania.

The Etruscan civilization in the Po Valley reached its height in the 400's B.C. It centered around Felsina (the modern Bologna). Etruscan control in Latium (including Rome) seems to have lasted throughout the 500's B.C., and in Campania for 60 or 70 years longer. The Gauls broke the Etruscans' hold on the Po Valley shortly after 400 B.C. Etruria itself passed wholly under the control of Rome early in the 200's B.C.

Influence on Rome. The historical importance of the Etruscans lies in their influence upon early Rome. Theirs was the first well-developed city culture with which the small farming communities in ancient Latium came into contact. Etruscan kings ruled Rome during the 500's B.C., when Rome itself grew from a village into a city. Rome became so prosperous and powerful under the Etruscan kings that it was able to rule most of Latium even after the last Etruscan king was driven out of the city.

Language and culture. The Etruscan language cannot yet be understood, although it is written in letters

WORLD BOOK map

Etruria, shown in yellow, was the home of the Etruscans. They gained control over much of the Italian peninsula.

much like Greek. Historians have a great many inscriptions in the language, but most are very brief. The language did not belong to the Indo-European family, like Latin and Greek, but it seems related to such obscure languages of Asia Minor as Lydian.

Etruscan art was greatly influenced by the Greeks. The most spectacular Etruscan remains are tombs. Many were decorated with wallpaintings. Hundreds of these tombs have been preserved. The Etruscans were skilled in metalworking and in *terra cotta* (molded and baked clay sculpture). They had a complicated set of religious ceremonies and were concerned about life after death. The Etruscans staged duels as human sacrifices at funerals. These duels later became Roman gladiator battles.

In the 500's and 400's B.C., the Etruscans were very wealthy. This wealth came partly from iron mining, but mainly from their control of trade in the western Mediterranean Sea.

Government. In general, scholars no longer believe the Romans borrowed their political institutions, such as the magistracies, from the Etruscans. But the influence of Etruria upon early Rome was strong and continuous.

The political unit of the Etruscans was the city, of which there were 12 in Etruria proper. A small aristocratic ruling class governed each city, sometimes through a king, more often through a magistracy. The cities themselves were joined in a common federation or league. Like the Greek leagues, it was not strong enough to prevent war between the cities, or even to ensure unity in the face of danger. With the Roman conquest of southern Etruria (405-396 B.C.), the league virtually ceased to function. Herbert M. Howe

See also Sculpture (Etruscan and Roman sculpture).

The Metropolitan Museum of Art, New York City, Harris Brisbane Dick Fund

Etruscan jewelry fashioned about 500 B.C. is made of gold and set with semiprecious stones. Craftworkers used designs of heads of women, satyrs, and gods on the ornaments.

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Étude, *AY tood* or *ay TOOD,* is a short musical composition written especially to enable students to practice a particular technique. Its purpose may be to strengthen certain fingers, to improve rhythm or accent, or to develop musical style. The word *étude* is French and means *a study.* Études are also written as compositions to be played for their own beauty. Among the most beautiful études are those written for piano by the Polish-born composer Frédéric Chopin. Thomas W. Tunks

Etymology, *eht uh MAHL uh jee,* is the study of the origin and development of words. Words, like peoples and nations, have histories that can be traced and recorded. Etymologists attempt to identify each change in a word's meaning and pronunciation for which there is historical evidence.

The modern study of etymology rests upon three basic principles that apply to all languages, past or present. First, the association between the sound and meaning of most words is random and not governed by any rules. In most cases, languages do not share the same word for an object or idea. For example, the word for *dog* is *chien* in French, *Hund* in German, *kutya* in Hungarian, and *inu* in Japanese. Second, because children learn to talk by imitating their elders, words are passed from generation to generation by imitation. Third, since languages are a form of social behavior, they always change gradually from generation to generation.

Etymons and cognates. Although there is no connection between the sound and meaning of most words, certain words in different languages resemble one another in both respects. The word for *father,* in certain languages, is an example. It is *padre* in Italian, *padre* in Spanish, *père* in French, and *pai* in Portuguese. These similarities occur because each word is a form of a single, earlier form—the Latin word *pater.* This earlier form is called an *etymon.*

The various words derived from an etymon are called *cognates* of one another. Sometimes the etymology of a word will reveal that it is cognate with words in another language. The various words for *father* already mentioned are examples. Another example is the English word *new,* which is cognate with the Latin word *novus* and the ancient Greek word *neos.* The etymon for these three words is *newos,* a form reconstructed from the prehistoric language called Proto-Indo-European. This

language is the ancestor of English, Latin, Greek, and most other European languages.

Different types of etymologies provide interesting perspectives on a word. The etymology for *scholar* is ultimately connected with the ancient Greek word *schole,* which means *leisure.* Thus, scholars are people who need leisure time to pursue their studies. Many words in English are derived from proper nouns. For example, the flower called the dahlia is named for a Swedish botanist of the 1700's named Andrew Dahl.

Some words are modifications of one or more other words. *Smog* is a blend of *smoke* and *fog.* The word *radar* comes from letters in the phrase "*ra*dio *d*etection *a*nd *r*anging." *Pep* is a shortened form of *pepper. Alone* is a combination of *all* and *lone. Scribble* is based on the Latin word *scribere,* which means *to write.* This Latin word is associated with such English words as *scripture, description, scribe,* and many other words that have *script-* or *scribe-* in their makeup. Robert J. Kispert

See also **Slang; Linguistics.**

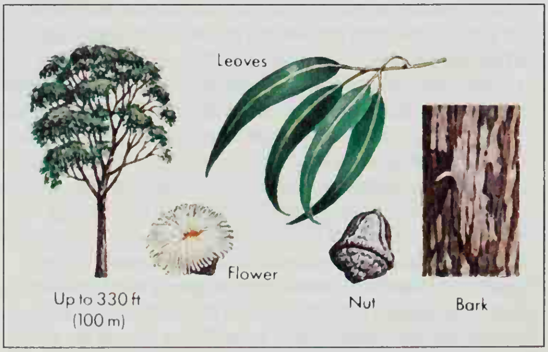
Eucalyptus, *yoo kuh LIHP tuhs,* is the name of a large group of trees native to Australia. These trees are useful for their oil, gum, and timber. Most eucalyptuses grow best in warm climates that have alternate wet and dry seasons. They have been successfully grown in Florida, southern California, and other parts of the southern United States. The type most frequently planted in North America is the *blue gum.* The trees grow rapidly and reach a gigantic size. The mature leaves are long, narrow, and leathery. The flowers are filled with nectar.

In Australia, eucalyptuses are the most important timber trees. The *jarrah* is an Australian eucalyptus with red wood much like mahogany. In California, eucalyptuses are planted around orange and lemon groves to break the force of the wind.

Manufacturers use eucalyptus lumber for ships, railroad ties, paving blocks, telegraph poles, fences, and piers. The trees furnish a resin, called *Botany Bay kino,* that protects wood against shipworms and other borers. The bark of some species of eucalyptus trees furnishes tannin, which is used in medicine. The leaves contain a valuable oil that is used as an antiseptic, a deodorant, and a stimulant. Alwyn H. Gentry

Scientific classification. Eucalyptus trees belong to the myrtle family, Myrtaceae. They make up the genus *Eucalyptus.* The blue gum is *E. globulus.* The jarrah is *E. marginata.*

See also **Australia** (Native plants).



WORLD BOOK illustration by John D. Dawson

The eucalyptus is an important commercial tree.

Eucharist. See **Communion; Transubstantiation.**

Euclid, *YOO klihd* (330?-270? B.C.), a Greek mathematician, is often called the father of geometry. He compiled, systematically arranged, and wrote portions of the mathematics textbook *Elements.* Euclid began with accepted mathematical truths called *axioms* and *postulates* (see **Axiom**). From them, he logically demonstrated 467 propositions of plane and solid geometry.

Euclid's textbook has probably had a greater influence on scientific thinking than any other work. It includes the *parallel postulate* and a well-known proof of the *Pythagorean theorem* (see **Geometry; Pythagorean theorem**).

Euclid wrote on most branches of mathematics that were known in his time. But only a few of his other writings have survived. They include works on conic sections, perspective, and pitfalls in geometry.

The place and date of Euclid's birth are uncertain, though it is known that he taught mathematics at the Museum, an institute in Alexandria, Egypt. Euclid probably studied in Athens and came to Alexandria shortly after 300 B.C. at the invitation of the Egyptian ruler Ptolemy I. According to the Greek philosopher Proclus, when Ptolemy I asked if there was a shorter way to the study of geometry than the *Elements,* Euclid replied, "there is no royal road to geometry." Ronald S. Calinger

Eugene (pop. 137,893; met. area pop. 322,959) is the second largest city in Oregon. Only Portland has more people. Eugene lies in a timber-rich area at the head of the fertile Willamette Valley in the western part of the state. For location, see **Oregon** (political map).

A shopping mall occupies more than 17 blocks in downtown Eugene. Nearby stand a convention center and a performing-arts center. Eugene is the home of the University of Oregon, Northwest Christian College, and Lane Community College. Eugene's major industries are the processing of lumber and the making of wood products. Other industries include food processing, the manufacture of machinery, metal production, and tourism.

Eugene developed from a village named for Eugene F. Skinner, a pioneer who settled in the area in 1846. It became an incorporated city in 1862. Eugene grew rapidly after the Oregon and California Railroad was built in 1871. It is the county seat of Lane County and has a council-manager form of government. Alton F. Baker III

Eugene III (? -1153) was elected pope in 1145. He had been a Cistercian monk and was strongly influenced by Saint Bernard of Clairvaux, the leader of the Cistercian order. Like Bernard, Eugene was a committed reformer and worked to improve the morals of the clergy.

Shortly after he became pope, Eugene called for a Second Crusade to recapture lost lands from the Muslims. He addressed a *bull* (papal letter) to King Louis VII of France urging him to undertake the Crusade and commissioned Bernard to organize support through preaching. Although Louis and King Conrad III of Germany led powerful armies to Asia Minor and Syria, the Crusade failed to recapture any lost Christian territory.

Eugene spent most of his reign outside Rome because the city had revolted against papal rule. He lived in France and Germany in 1147 and 1148 where he held church councils. He finally negotiated a return to Rome in 1153. Eugene was born in Pisa. His given name was Bernardo. Kenneth Pennington

See also **Bernard of Clairvaux, Saint.**

Eugene IV (1383-1447) was elected pope in 1431. His troubled reign was marked by a long struggle with the Council of Basel (1431-1449) over whether the pope or church councils held supreme authority in the church. In 1434, civil disturbances in Rome forced Eugene to flee to Florence. But settlement with his enemies permitted him to return to Rome in 1443. Eugene's stubborn defense of papal privileges prevailed over the supporters of the council's movement, reaffirming the pope's authority as head of the church. Eugene also enhanced papal prestige with his temporary success at reunification with several Eastern churches, including the Greek Orthodox Church. Reunification with it began at the Council of Ferrara-Florence in 1438.

Eugene was born in Venice, where he lived as a monk in his youth. His given and family name was Gabriel Condulmaro. He won admiration for his simple, pious personal life. Charles L. Stinger

Eugenics, *yoo JEHN ihks,* is a method that aims at improving the human race by selection of parents based on their inherited characteristics. *Eugenists* (people who study eugenics) want to improve future generations by encouraging persons who are above average mentally and physically to have more children. This is called *positive eugenics.* Eugenists also propose that persons who are below average mentally or physically have fewer children. This is called *negative eugenics.*

Scientists still cannot predict with great accuracy the presence of desirable traits, such as intelligence and physical fitness. However, they understand the inheritance of certain physical and mental abnormalities. They can identify persons who are healthy themselves, but carry a weakness for certain diseases in their *genes* (see Gene). For example, a blood test will reveal the presence of a hidden defective gene that causes the blood disease *sickle cell anemia.* Eugenists warn against a marriage of two persons who are carriers of the defective gene, because some of the couple's children may have the disease. In many inherited diseases, children show the defect that their parents only carried.

Eugenics began with the research of Sir Francis Galton in the 1880's, but it has not won widespread acceptance. Many people fear that a eugenics program would take away basic human rights, such as people's rights to marry whom they choose. They also fear that control of reproduction might be misused. Many persons object to such controls because of religious beliefs.

Some states have laws that are aimed at preventing persons with known defects from having children. However, most eugenic action comes from educational programs and voluntary decisions. Daniel L. Hartl

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Breeding
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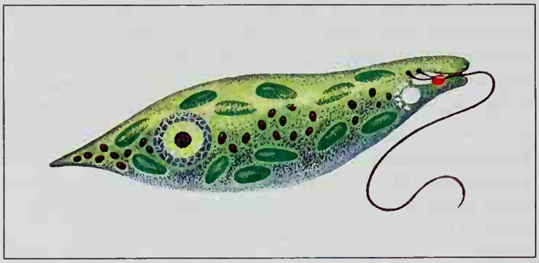
Galton, Sir Francis
Genetics
Heredity
Pearson, Karl
Reproduction, Human

Eugénie Marie de Montijo, *yu zhay NEE ma REE thay mawn TEE hoh* (1826-1920), became empress of France as the wife of Napoleon III. A Spanish countess, she married Napoleon in 1853, soon after he became emperor. The empress set standards for beauty and fashion in Napoleon's court but became noted for her extravagance. Politically influential, she favored the Roman Catholic and conservative group and tried to delay a more liberal government in France. She urged a warlike policy on the eve of the Franco-Prussian War. After 1870, she was forced to live in exile. Empress Eugénie was born in Granada, Spain. Peter N. Stearns

Euglena, *yoo GLEE nuh,* is a *genus* (group) of microscopic, one-celled organisms. There are about 150 species of euglenas. They live in fresh water, and are especially common in warm seasons when they may form a green scum on the surfaces of small ponds or drainage ditches.

Euglenas have spindle-shaped bodies, and range in size from $\frac{1}{1000}$ to $\frac{1}{100}$ of an inch (0.025 to 0.254 millimeter) long. Most species are green because they contain *chlorophyll,* the green coloring material found in most types of plants. These species get energy from sunlight. Some species also eat tiny particles of living matter. Euglenas use a *flagellum* (a whiplike appendage) that sticks out from the body, to move.

Euglenas are often used in classrooms for study and in laboratory research because they are easy to find, grow, and keep. They reproduce rapidly and can be studied under an ordinary microscope. John O. Corliss



WORLD BOOK illustration by James Teason

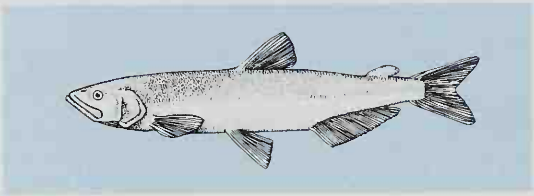
Euglenas are tiny freshwater organisms.

Scientific classification. Euglenas traditionally have been classified in either the plant kingdom, Plantae, or the animal kingdom, Animalia. Many scientists now classify them in the kingdom Protista.

Eulachon, *YOO luh kahn,* is a saltwater fish about 9 inches (23 centimeters) long. It lives in the North Pacific from the Bering Sea to central California. From March to May, eulachons swim up rivers to spawn. At that time, the fish are caught with dip nets and seines in shallow parts of certain tributaries of the lower Columbia and Fraser rivers. The eulachon is a popular food fish. Eulachons are also called *candlefish* because Indians of the West Coast used dried eulachons as candles.

David W. Greenfield

Scientific classification. The eulachon belongs to the smelt family, Osmeridae. It is *Thaleichthys pacificus.*



WORLD BOOK illustration by Patricia Wynne

The eulachon is a saltwater fish.

Eulenspiegel, *OY lehn SHPEE gehl,* **Till,** was a practical joker whose pranks became a favorite subject of writers and musicians. Till is said to have lived in Germany during the first half of the 1300's. According to tradition, he was born in Braunschweig and was the son of a peasant farmer. Many tales were told about the pranks Till played on the *burghers* (townfolk) and the nobility, the traditional enemies of the peasant class. Till made fun of his enemies and cheated them out of money, while pretending to be stupid himself.

The first collection of Till stories was published in German during the late 1400's. Translators retold them in many other languages. The first version of Till stories in English, called *Howleglas (Owl-glass),* dates from 1560. Hans Sachs of Germany wrote plays and songs about Till during the 1500's. *Till Eulenspiegel's Merry Pranks* (1895) is a famous orchestral tone poem by Richard Strauss of Germany. James F. Poag

Euler, *OY luhr,* **Leonhard** (1707-1783), a Swiss mathematician, became famous for his great output of original mathematics and for the wide range of subjects he covered. He did much of his work after he became blind in one eye in 1735 and totally blind in 1766. Euler contributed new ideas in calculus, geometry, algebra, number theory, and probability. He also worked in many areas of applied mathematics, such as acoustics, optics, astronomy, artillery, navigation, statistics, and finance. Euler was born on April 15, 1707, in Basel, Switzerland. He died on Sept. 18, 1783. Arthur Gittleman

Euphorbiaceae. See **Spurge.**

Euphrates River, *yoo FRAY teez,* is the longest river in southwestern Asia. It is about 1,700 miles (2,736 kilometers) long and forms part of the historic Tigris-Euphrates river system.

The Euphrates rises in a mountainous area of eastern Turkey and flows southwest through the country into Syria. In Syria, it turns southeast and gradually descends until it reaches low, flat land. After leaving Syria, the Euphrates cuts across Iraq. At the town of Al Qurnah, Iraq, it joins the Tigris, forming a river called the Shatt al Arab, which flows into the Persian Gulf.

The area near and between the Euphrates and Tigris rivers in Iraq has the country's most fertile soil. Most of Iraq's people live there. Large ships cannot navigate the Euphrates because of its shallow waters and shifting

WORLD BOOK map

Location of the Euphrates River

sandbars. The river serves chiefly as a source of irrigation water and hydroelectric power. In some places, water wheels have been used since ancient times to lift water from the Euphrates onto adjoining land. Also, canals along the river drain water from it to irrigate crops. Dams store water that is used to generate hydroelectric power for Iraq, Syria, and Turkey.

The world's first civilization developed in the region around the Euphrates and Tigris rivers. This advanced culture arose in Sumer about 3500 B.C. Babylonia and other early civilizations also thrived in this region. The ruins of the famous ancient city of Babylon lie along the Euphrates. John Kolars

See also **Babylon; Mesopotamia; Tigris River; World, History of the** (The Tigris-Euphrates Valley).

Euphrosyne. See **Graces.**

Eurasia. See **Europe** (The land).

Euripides, *yoo RIHP uh deez* (about 480-406 B.C.), was the third of the three great writers of Greek tragedy. He dealt with the same mythological heroes as the other two, Aeschylus and Sophocles. But he showed the heroes as ordinary people and used his plays to criticize political, social, and religious ideas of the time. He used much simpler language than the earlier playwrights, but his plots were more complicated.

Euripides was not popular during his lifetime. His ideas were not always the accepted ones, and he sometimes offended writers and politicians. The Greek playwright Aristophanes satirized Euripides in several comedies (see **Aristophanes**). But Euripides's plays have been revived more frequently than those of his rivals.

Euripides wrote about 90 plays. Eighteen tragedies and a *satyr play* survive. A satyr play is a type of comedy presented at the conclusion of a trilogy. Euripides's satyr play, *Cyclops,* is probably one of his later works. The tragedies are *Rhesus,* Euripides's earliest existing play; *Alcestis* (438 B.C.); *Medea* (431); *The Children of Heracles* (about 430); *Hippolytus* (428); *Andromache* (about 426); *Hecuba* (about 424); *The Suppliants* (about 422); *Heracles* (about 417); *Electra* (about 417); *The Trojan Women* (415); *Iphigenia in Tauris* (about 412); *Helen* (412); *Ion* (about 412); *The Phoenician Women* (about 410); *Orestes* (408); and two plays performed after his death, *Bacchae* (405?); and *Iphigenia in Aulis* (405?).

Euripides was born on the island of Salamis. He grew up in Athens. As a youth, Euripides was trained to be an athlete. He also studied philosophy and literature. His instructors included the philosophers Anaxagoras and Protagoras. Euripides began to write plays before the age of 20 and entered a contest for playwrights when he was 25. From this time on, he wrote plays steadily. Euripides became a friend of the philosopher Socrates, and some critics believe Socrates influenced his writing.

Unlike Aeschylus and Sophocles, Euripides seems to have played no active role in Athenian public life. In about 408, Euripides left Athens. He went to Thessaly, in northern Greece, and then to Macedonia, where he wrote the plays *Bacchae* and *Iphigenia in Aulis.*

Luci Berkowitz

See also **Drama** (Greek drama); **Greek literature.**

Euro, *YUR oh,* is the basic monetary unit of 12 of the 15 members of the European Union. The 12 countries are Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and

Spain. Most of these countries adopted the euro on Jan. 1, 1999.

When the euro was adopted, companies, banks, and stock exchanges in the participating nations began to carry out many of their noncash transactions in euros. Euro notes and coins replaced the countries' traditional currencies in early 2002. C. Randall Henning

Eurodollar, *YUR oh DAHL uhr,* refers to a transfer of credit designated in United States dollars from a U.S. bank to a foreign bank. Banks that handle Eurodollars are sometimes called *Eurobanks.* Most of these banks are in Europe, but Eurobanks also operate in international financial centers in Asia and even in New York City.

Eurodollar deposits are subject to few restrictions. For example, banks outside the United States are not required to keep reserves against such deposits. Furthermore, interest rates are unregulated. Critics are concerned that the Eurodollar market limits national control over money and credit. However, the Eurodollar system has helped reduce the differences in interest rates between lending and borrowing countries.

Robert M. Stern

Europa, *yu ROH puh,* in Greek mythology, was the beautiful daughter of Agenor, king of the city of Tyre in Phoenicia. The god Zeus fell in love with her. He disguised himself as a handsome white bull and tempted Europa to climb up onto his back. Zeus then swam to the island of Crete and made love to her. Zeus and Europa had three sons: Minos, Rhadamanthys, and Sarpedon.

Agenor ordered his sons to search for Europa, but they never found her. Agenor's son Cadmus founded the Greek city of Thebes while searching (see **Cadmus**). Europa eventually married Asterius, the king of Crete.

The continent of Europe is named for Europa. Zeus's disguise as a bull is commemorated by the constellation Taurus and as a sign of the zodiac. Justin M. Glenn

Europa, *yu ROH puh,* is a large moon of Jupiter. Its surface is made of ice, which may have an ocean of water beneath it. Such an ocean could provide a home for living things. The surface layer of ice or ice and water is 50 to 100 miles (80 to 160 kilometers) deep. The satellite has an extremely thin atmosphere. Electrically charged particles from Jupiter's radiation belts continuously bombard Europa.

Europa is one of the smoothest bodies in the solar system. Its surface features include shallow cracks, valleys, ridges, pits, blisters, and icy flows. None of them extend more than a few hundred yards or meters upward or downward. In some places, huge sections of the surface have split apart and separated. The surface of Europa has few *impact craters* (pits caused by collisions with asteroids or comets). The splitting and shifting of the surface and disruptions from below have destroyed most of the old craters.

Europa's interior is hotter than its surface. This internal heat comes from the gravitational forces of Jupiter and Jupiter's other large satellites, which pull Europa's interior in different directions. As a result, the interior flexes, producing heat in a process known as *tidal heating.* The core of Europa may be rich in iron, but most of the satellite is made of rock.

Europa's diameter is 1,945 miles (3,130 kilometers), slightly smaller than Earth's moon. Europa takes 3.55 days to orbit Jupiter at a distance of 416,900 miles (670,900 kilometers). The Italian astronomer Galileo discovered Europa in 1610. Much of what is known about it comes from data gathered by a space probe, also named Galileo, that reached Jupiter in 1995.

William B. McKinnon

See also **Jupiter; Satellite.**

The Rape of Europa (1600's), a copy of a lost original oil painting by Guido Reni; Musée des Beaux-Arts, Tours, France (J. J. Moreau)

Europa was a beautiful young princess in Greek mythology. The god Zeus fell in love with her. Disguising himself as a handsome white bull, Zeus carried Europa off to the island of Crete.

NASA

The surface of Europa, a moon of Jupiter, consists mostly of huge blocks of ice that have cracked and shifted about, suggesting that there may be an ocean of liquid water underneath.

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© John Elk, Bruce Coleman Inc.

Europe's rural and urban areas are vitally important to the continent's economy. The Cotswold Hills region of southern England includes vast scenic areas of fertile farmland, *top.* The city of Bergen, Norway, lies at the head of By Fiord and ranks as an important seaport. Like many other European cities, Bergen has a picturesque old section, *bottom.*

Europe

Europe is one of the smallest of the world's seven continents in area but one of the largest in population. All of the continents except Australia have more land than Europe. But only Asia and Africa have more people. About one-eighth of the world's people live in Europe. Europe is more densely populated than all the other continents except Asia.

Europe extends from the Arctic Ocean in the north to the Mediterranean Sea in the south and from the Atlantic Ocean in the west to the Ural Mountains in the east. The continent of Europe occupies the western fifth of the world's largest land mass. Asia occupies the rest of this land.

The 47 countries of Europe include the world's largest country, Russia, as well as the world's smallest, Vatican City. Russia lies partly in Europe and partly in Asia. By world standards, most European countries are average or small in size. The five smallest countries—Andorra, Liechtenstein, Monaco, San Marino, and Vatican City—are smaller than many of Europe's cities.

The people of Europe represent a variety of cultural

backgrounds. For centuries, they have spoken different languages and followed different cultural traditions.

Europe was a world leader in economic development and continues to be one of the world's leading industrial and agricultural centers. The continent has many rich deposits of coal and iron ore. It has some of the richest farmland in the world.

The many cultural landmarks and natural beauties of Europe attract visitors from all parts of the world. Exhibits in such museums as the Louvre in Paris thrill art lovers. Masterpieces of architecture include the temples of ancient Greece and Rome and the Gothic cathedrals of France, Germany, and Italy. London is rich in history and royal pageantry, with famous palaces and government buildings. Europe's historic Rhine River winds past steep cliffs dotted with the ruins of castles built hundreds of years ago. Among the continent's many other attractions are the snow-covered Alps of Switzerland, the colorful tulip fields of the Netherlands, the canals of Venice, and the sunny beaches of the Riviera.

Europe has had a great impact on the history of the world. It is the birthplace of Western civilization. From the time of the ancient Greeks, Europe's political ideas, scientific discoveries, arts and philosophies, and religious beliefs have spread to other parts of the world. The civilizations of Australia, Canada, Latin America, New Zealand, and the United States largely developed from European civilization.

The most important European civilizations of ancient times developed in the region around the Mediterranean Sea. The earliest of these civilizations began about 3000 B.C. on islands in the Aegean Sea, east of Greece.

The two most influential ancient European civilizations were those of the Greeks and the Romans. Greek civilization reached its height in the 400's and 300's B.C. The Greeks made lasting contributions to art, science, philosophy, and government. The Romans, who lived on the Italian Peninsula, adopted much of Greek civilization. They began to expand their territory in the 200's B.C.,

© Taurus from Campagne-Campagne

Masterpieces of architecture throughout Europe attract visitors from all over the world. The famous St. Basil's Cathedral, *shown here,* stands on Red Square in the heart of Moscow.

The contributors of this article are Hugh D. Clout, Professor of Geography at University College, London; M. Donald Hancock, Professor of Political Science and Director, Center for European Studies, at Vanderbilt University; and William M. Reddy, Professor of History and Cultural Anthropology at Duke University.

Facts in brief

Area: 4,038,000 mi^2 (10,458,000 km^2). *Greatest distances*—east-west, about 4,000 mi (6,400 km); north-south, about 3,000 mi (4,800 km). *Coastline* —37,887 mi (60,973 km).

Population: *Estimated 2002 population*—701,188,000; density, 174 per mi^2 (67 per km^2).

Elevation: *Highest*—Mount Elbrus, 18,510 ft (5,642 m) above sea level. *Lowest*—shore of the Caspian Sea, 92 ft (28 m) below sea level.

Physical features: *Chief mountain ranges*—Alps, Apennines, Balkans, Carpathians, Caucasus, Pyrenees, Sierra Nevada. *Chief rivers*—Danube, Don, Elbe, Oder, Rhine, Rhône, Seine, Volga. *Chief lakes*—Caspian Sea, Ladoga. *Chief islands*—Balearic Islands, Corsica, Crete, Faroe Islands, Great Britain, Iceland, Ireland, Malta, Sardinia, Sicily.

Number of countries: 47.

© Harvey Lloyd, The Stock Market

Canals and rivers form an important transportation system in many parts of Europe. Boats called *gondolas, shown here,* carry people throughout the city of Venice, Italy.

and they eventually built an empire that included much of Europe and parts of Africa and Asia.

The Roman Empire ended in the A.D. 400's, and a period of European history called the *Middle Ages* began. There were no strong nations in Europe during most of this period. The Roman Catholic Church had the greatest influence in politics, education, arts, and religion.

The early 1300's marked the beginning of the Renaissance, a period in which Europeans made great achievements in the arts and learning. By the time the Renaissance ended, about 1600, Europe was moving into a period of rapid economic, political, and scientific progress. By the early 1700's, Britain, France, and several other European nations had become the leading powers of the world. These nations established colonies in Africa, Asia, and America, and they gained great wealth through trade with the colonies.

The Industrial Revolution, which marked the start of modern industry, began in Europe during the 1700's. The continent soon became the manufacturing center of the world, and European nations established more and more overseas colonies. Colonies supplied raw materials to European industry and were markets for Europe's manufactured goods. Most of Africa and about a third of Asia came under European colonial rule. But during the 1900's, European nations lost almost all their colonies.

World War I (1914-1918) and World War II (1939-1945) started in Europe. The wars brought great destruction to the continent. They also led to changes in the form of government in many European nations and to the creation of several countries.

Communist governments were established in much of Europe after World War II, and the continent was divided between Communist and non-Communist nations. The non-Communist nations made up what came to be called *Western Europe*. The Communist countries made up *Eastern Europe*.

From the late 1940's through the early 1960's, Europe was a center of the Cold War struggle between the world's Communist and non-Communist forces. In the late 1960's, relations between Eastern and Western Europe began to improve. Then, in the late 1980's, a series of reforms in the Communist Soviet Union gave the Soviet people more freedom. The reforms led to demands for greater freedom and an end to Communist rule across Eastern Europe. Beginning in 1989, countries throughout the region discontinued one-party rule.

In 1949, Germany had been divided into two nations—Communist East Germany and non-Communist West Germany. In 1990, the two nations were unified into the single non-Communist nation of Germany.

In 1991, the Soviet Union went through a political upheaval. First, Communist rule ended there after conservative Communist officials failed in an attempt to overthrow Soviet leader Mikhail Gorbachev. Following the attempt, the republics of Estonia, Latvia, and Lithuania—which the Soviet Union had taken over in 1940—became recognized as independent countries. By the end of the year, most of the other Soviet republics had declared their independence. On December 25, 1991, the Soviet Union was formally dissolved. Besides Estonia, Latvia, and Lithuania, Europe's new countries included Belarus, Moldova, and Ukraine. Several other Soviet republics became independent countries that lie partly in Europe and partly in Asia. These countries include Azerbaijan, Georgia, Kazakhstan, and Russia.

Also in 1991, three of Yugoslavia's six republics—Croatia, Macedonia, and Slovenia—declared their independence. In early 1992, a fourth republic, Bosnia-Herzegovina, declared its independence. The two remaining republics, Serbia and Montenegro, stayed together as a much smaller Yugoslavia.

During the late 1900's, though some countries divided, many of Europe's nations took steps toward unity. For example, a number of them formed an association called the European Union (EU). Through the EU, they cooperate with one another in some political matters and work to unite their resources into a single economy.

© European Commission Delegation, Washington, D.C.

The European Union works to provide common economic and other policies for its member countries. This photograph shows the 1992 signing of the Treaty on European Union, also called the Maastricht Treaty. The treaty, which took effect in 1993, established the European Union.

Independent countries of Europe*

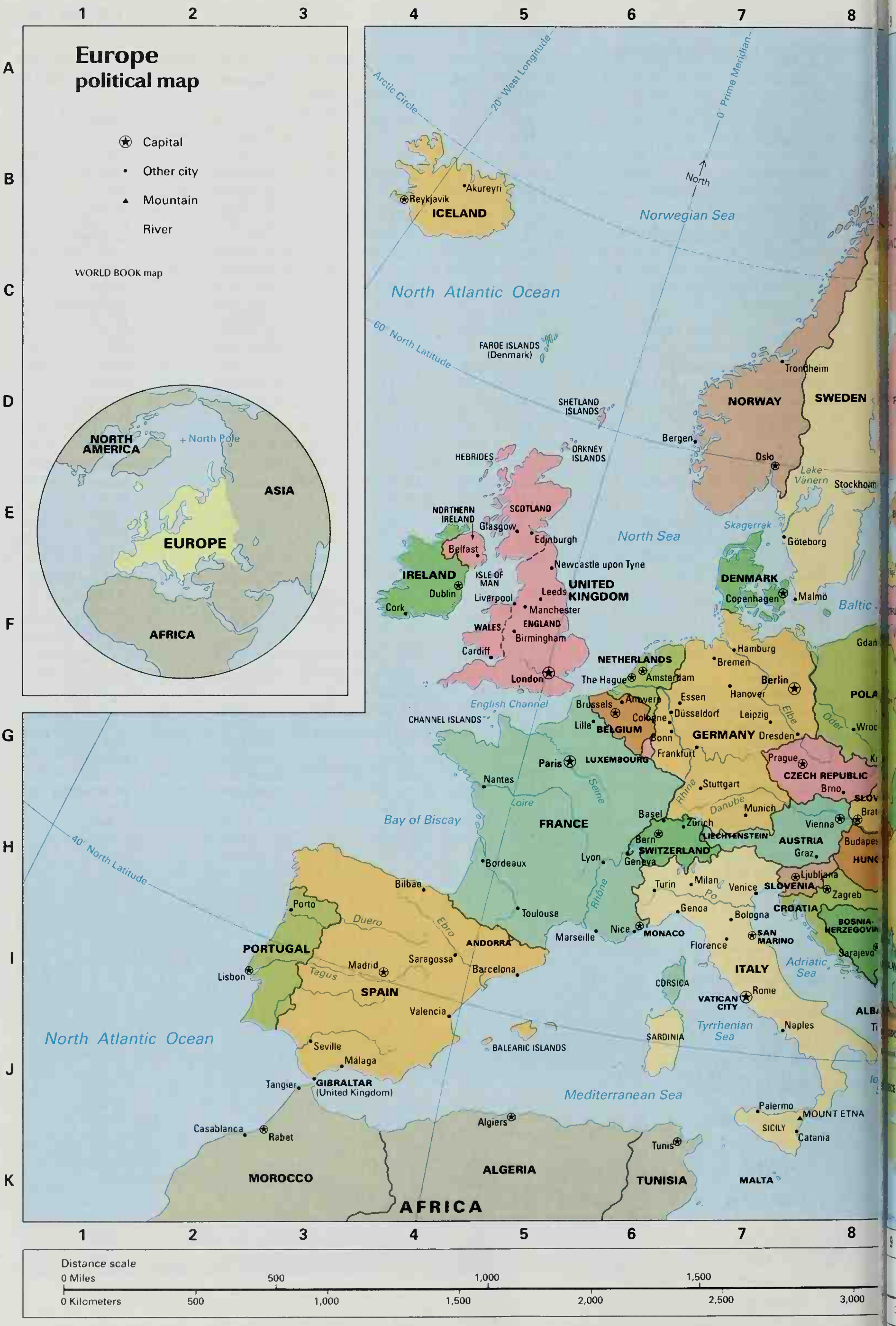
Map key	Name	Area in mi²	Area in km²	Population	Capital
J 8	**Albania**	11,100	28,748	3,152,000	Tiranë
I 5	**Andorra**	175	453	69,000	Andorra la Vella
H 7	**Austria**	32,378	83,859	8,255,000	Vienna
I 14	**Azerbaijan (European)**	5,521	14,300	2,356,000	Baku
G10	**Belarus**	80,155	207,600	10,175,000	Minsk
G 6	**Belgium**	11,783	30,519	10,165,000	Brussels
I 8	**Bosnia-Herzegovina**	19,741	51,129	3,890,000	Sarajevo
I 10	**Bulgaria**	42,823	110,912	8,128,000	Sofia
H 8	**Croatia**	21,829	56,538	4,460,000	Zagreb
G 8	**Czech Republic**	30,450	78,864	10,215,000	Prague
E 7	**Denmark**	16,639	43,094	5,307,000	Copenhagen
E 9	**Estonia**	17,413	45,100	1,368,000	Tallinn
D 9	**Finland**	130,559	338,145	5,193,000	Helsinki
H 5	**France**	212,935	551,500	59,411,000	Paris
I 13	**Georgia (European)**	5,651	14,637	497,000	Tbilisi
G 7	**Germany**	137,735	356,733	82,286,000	Berlin
J 9	**Greece**	50,949	131,957	10,647,000	Athens
H 8	**Hungary**	35,920	93,032	9,956,000	Budapest
B 4	**Iceland**	39,769	103,000	286,000	Reykjavík
F 4	**Ireland**	27,137	70,284	3,811,000	Dublin
I 7	**Italy**	116,320	301,268	57,092,000	Rome
G13	**Kazakhstan (European)**	46,603	120,700	486,000	Astana
E 9	**Latvia**	24,942	64,600	2,305,000	Riga
H 7	**Liechtenstein**	62	160	34,000	Vaduz
F 9	**Lithuania**	25,174	65,200	3,647,000	Vilnius
G 6	**Luxembourg**	998	2,586	438,000	Luxembourg
J 9	**Macedonia**	9,928	25,713	2,048,000	Skopje
K 7	**Malta**	122	316	394,000	Valletta
H10	**Moldova**	13,012	33,700	4,383,000	Chisinau
I 6	**Monaco**	0.58	1.49	35,000	Monaco
F 6	**Netherlands**	16,033	41,526	15,849,000	Amsterdam
D 7	**Norway**	149,405	386,958	4,505,000	Oslo
G 8	**Poland**	124,808	323,250	38,835,000	Warsaw
I 3	**Portugal**	34,340	88,941	9,863,000	Lisbon
H 9	**Romania**	92,043	238,391	22,171,000	Bucharest
F 10	**Russia (European)**	1,663,870	4,309,400	108,318,000	Moscow
I 7	**San Marino**	24	61	28,000	San Marino
H 8	**Slovakia**	18,924	49,012	5,404,000	Bratislava
H 8	**Slovenia**	7,821	20,256	1,982,000	Ljubljana
I 4	**Spain**	195,365	505,992	39,567,000	Madrid
D 8	**Sweden**	173,732	449,964	8,947,000	Stockholm
H 6	**Switzerland**	15,940	41,284	7,445,000	Bern
J 10	**Turkey (European)**	9,120	23,621	7,536,000	Ankara
H10	**Ukraine**	233,090	603,700	50,083,000	Kiev
F 5	**United Kingdom**	94,248	244,101	58,959,000	London
I 7	**Vatican City**	0.17	0.44	1,000	—
I 8	**Yugoslavia‡**	39,449	102,173	10,655,000	Belgrade

Dependencies in Europe*

Map key	Name	Area in mi²	Area in km²	Population	Capital	Status
†	**Azores**	868	2,247	248,000	Ponta Delgada	Autonomous region of Portugal
G 5	**Channel Islands**	76	197	155,000	St. Peter Port; St. Helier	British crown dependencies
C 5	**Faroe Islands**	540	1,399	42,000	Tórshavn	Self-governing community of Denmark
J 3	**Gibraltar**	2.3	6	25,000	Gibraltar	British overseas territory
E 5	**Man, Isle of**	221	572	81,000	Douglas	British crown dependency

*Each country and dependency in Europe has a separate article in *World Book*. †Not on map; located about 800 miles (1,300 kilometers) west of Lisbon, Portugal.
‡In 2002, plans were made to dissolve Yugoslavia and replace it with a loose confederation called Serbia and Montenegro.
Populations are 2002 estimates for countries and 2002 and earlier estimates for dependencies based on the latest figures from official government and United Nations sources.

Europe political map



NOVAYA ZEMLYA
Barents Sea
KOLGUYEV ISLAND
40° East Longitude
60° East Longitude
80° East Longitude
North
Murmansk
FINLAND
Helsinki
White Sea
Arkhangelsk
Northern Dvina
Lake Onega
Lake Ladoga
St. Petersburg
Tallinn
ESTONIA
Lake Peipus
Rybinsk Reservoir
Gorki Reservoir
Volga
Nizhniy Novgorod
Riga
LATVIA
Moscow
LITHUANIA
Vilnius
Minsk
BELARUS
Western Dvina
Neman
Oka
Don
URAL MOUNTAINS
ASIA
EUROPE
ASIA
RUSSIA
WEST SIBERIAN PLAIN
Ob
Irtysh
Omsk
Yekaterinburg
Perm
Chelyabinsk
Kama
Magnitogorsk
Kazan
Kuybyshev Reservoir
Ural
Orenburg
Samara
KAZAKHSTAN
Saratov
Volgograd Reservoir
Volgograd
Aral Sea
Syr Darya
UZBEKISTAN
Amu Darya
Kiev
Kharkov
Lvov
UKRAINE
Dnepr
Donetsk
Dnepropetrovsk
Dnestr
Rostov-on-Don
Astrakhan
MOLDOVA
Chisinau
Odessa
Sea of Azov
CRIMEA
Yalta
Cluj-Napoca
ROMANIA
Brasov
Bucharest
Danube
BULGARIA
Sofia
Plovdiv
Black Sea
MOUNT ELBRUS
GEORGIA
Tbilisi
Batumi
AZERBAIJAN
Baku
ARMENIA
Yerevan
MOUNT ARARAT
Caspian Sea
TURKMENISTAN
Ashgabat
Istanbul
Bosporus
TURKEY
Ankara
Lake Van
Lake Urmia
Tehran
Aegean Sea
Athens
TURKEY
ASIA
IRAN
Tigris
Baghdad
Euphrates
SYRIA
IRAQ
RHODES
CRETE
Nicosia
CYPRUS
Beirut
LEBANON
Damascus
Persian Gulf
9 10 11 12 13 14 15 16
A B C D E F G H I J K
2,500 3,000 3,500 4,000
3,500 4,000 4,500 5,000 5,500 6,000

People

The vast majority of Europeans are descended from various nomadic peoples who lived in the continent during ancient times. Many of these groups roamed from place to place and mixed with other groups they met. For example, the ancestors of the British people included such groups as the Angles, Celts, Danes, Jutes, and Saxons.

In the last half of the 1900's, large numbers of people from Asia and northern Africa moved into countries of western Europe. However, people of Asian or African descent still make up only a small fraction of the continent's population.

Population. Europe is the third largest continent in population. Only Asia and Africa have more people. About 701 million people, or about an eighth of the world's population, live in Europe.

About 108 million people live in the part of Russia that lies in Europe. No other European country has nearly as

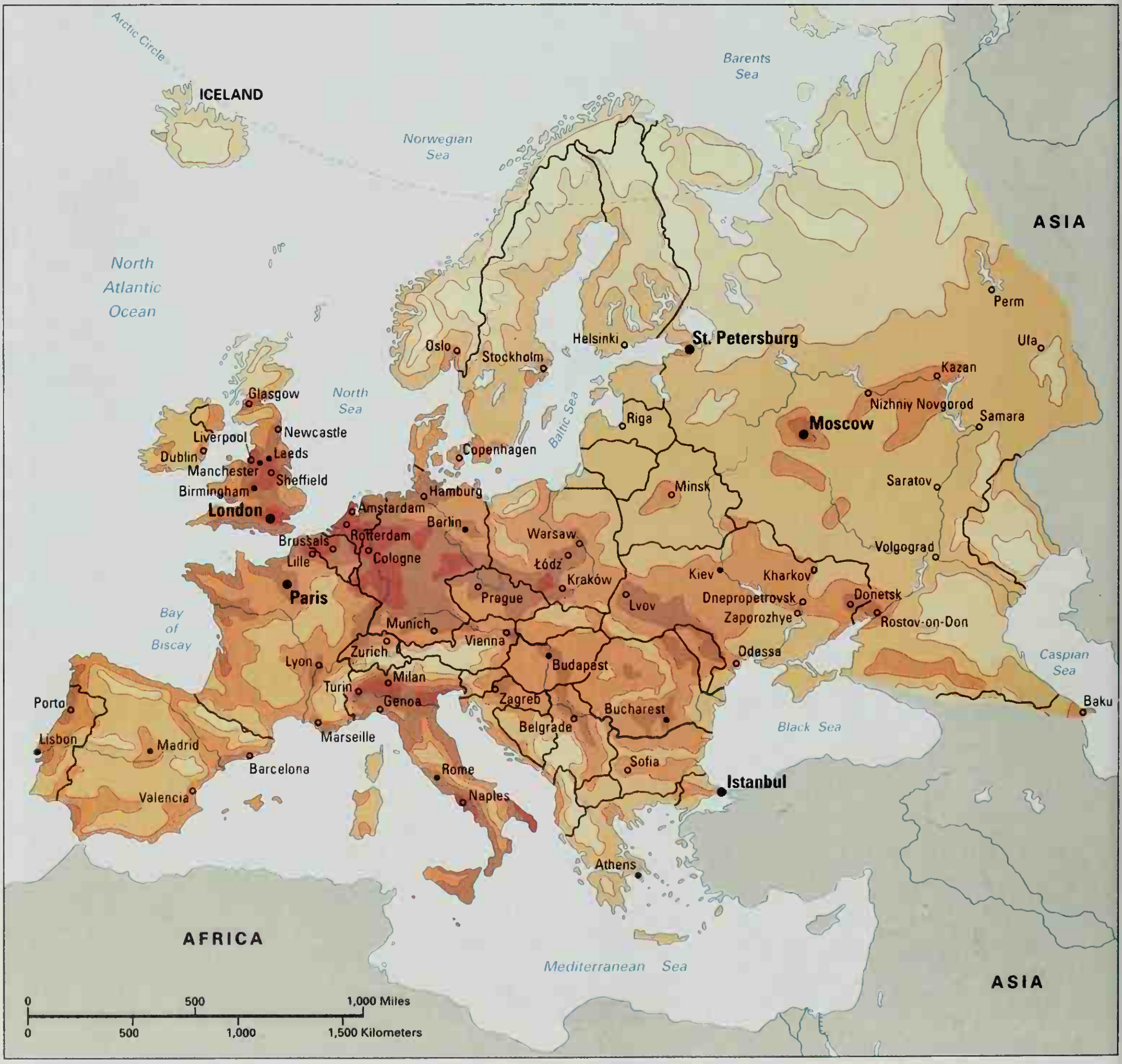
Where the people of Europe live

Europe is the third largest continent in population, after Asia and Africa. Most of the people of Europe live in cities. This map shows where Europeans live and the location of most of the largest cities. Heavily populated areas are shown in the darker colors.

Persons per sq. mi.	Persons per km²
More than 500	More than 200
250 to 500	100 to 200
125 to 250	50 to 100
25 to 125	10 to 50
2 to 25	1 to 10
Less than 2	Less than 1

Major urban centers
- More than 5 million inhabitants
- 2 million to 5 million inhabitants
- Less than 2 million inhabitants

WORLD BOOK map



AP/Wide World

Conflict among ethnic groups has often broken out in Europe when members of neighboring ethnic groups dislike or distrust one another. In this photo, ethnic Albanians in the Serbian province of Kosovo protest the Serbs' violence against them.

many people. Vatican City is the smallest nation in Europe by population. It also has the fewest number of people of any country in the world. Only about 1,000 people live in Vatican City.

Europe has an average of about 174 people per square mile (67 persons per square kilometer). Europe and Asia rank as the two most densely populated continents in the world. In Europe, as in all continents, the people are not distributed evenly. Most of Europe has far less than the average density, but parts of it have far more. For example, large areas of northern Europe are nearly uninhabited. However, the Netherlands has about 1,000 people per square mile (385 per square kilometer), making it one of the world's most densely populated countries.

Ethnic groups. The peoples of Europe have widely varying cultures. Europe's *ethnic groups* are one of its most important features.

An ethnic group consists of a large number of people with the same cultural background. Members may be united by the same language, the same religion, a common ancestry, or all these characteristics. Europe has dozens of ethnic groups, and many countries have two or more of them. For example, the people of Belgium include the Flemings and the Walloons.

Ethnic groups can provide their members with a sense of belonging. They can establish standards of behavior for their members and can also preserve artistic, religious, and other traditions.

But in many cases, members of neighboring ethnic groups dislike and distrust each other. These feelings often lead to fighting among groups, both within and between countries. Such conflicts in modern Europe have included fighting between the English and the Irish and between Serbs and the ethnic Albanians in Serbia's province of Kosovo.

However, many European ethnic groups have gradually forgotten their differences and now think of themselves as members of some national group, such as Danes or Italians. In parts of Europe, some people have even begun to think of themselves less as members of national groups and more as Europeans.

© Les Stone, Sygma

Turkish residents of Germany are an example of the ethnic diversity found in many European countries. A large number of people from Asia and northern Africa have moved to Europe.

Ways of life

© Robert Frerck, Woodfin Camp, Inc.

Country life in much of Europe is based on agriculture. This Spanish farmer uses modern farm machinery. But some farmers use the old-fashioned farming methods of their ancestors.

© Mike Yamashita, Woodfin Camp, Inc.

City life in Europe bustles with people and activity. In this photo, bicyclists compete with motorists for space on the streets of Amsterdam, the capital and largest city of the Netherlands.

Major differences in European ways of life have long existed between the east and the west, the north and the south, and urban and rural areas. Customs, languages, religions, and educational systems have always varied between these groups.

For many years, the Communist governments of eastern Europe brought about additional differences between the east and west. The Communists severely limited the artistic, economic, political, and social freedom of the people. But in the late 1980's and early 1990's, Communists lost control in the region, and the people gained new freedoms.

The northern regions of Europe generally have become more industrial and urbanized than the southern regions. These developments widened the gap between life in the north and the south. Throughout Europe, rural people tend to follow traditional ways of life more than do urban people.

Certain developments brought about a lessening of these differences, especially in the last half of the 1900's. These developments included industrialization, rapidly growing cities, and rising standards of living. People generally begin to follow similar ways of life after they move to cities, find industrial jobs, and increase their earnings. Also, some city ways have spread to many rural areas of Europe.

In spite of their many differences, Europeans share some basic attitudes and beliefs. For example, many Europeans place great importance on the family. They consider it the center of their social and economic lives. Many Europeans also believe strongly in the importance of social class, and they expect the government to provide for their welfare and to play a central role in the nation's economic affairs.

Another widely held attitude among Europeans is a strong belief in the importance of the past. Europeans take great pride in the outstanding artistic, educational, and political achievements that the peoples of the continent made hundreds, or even thousands, of years ago.

City life. The rapid growth of industry and business in many large cities of Europe has drawn many people from rural areas. As a result, these cities have become crowded, and suburbs have developed around them.

Europe has some of the world's largest and most famous cities. Moscow, the capital of Russia, is the largest city in Europe. London, the capital of the United Kingdom, and Paris, the capital of France, rank among the largest urban centers of the world. London is important in international finance. Paris has long been a world capital of fashion, art, and learning.

Cities in western Europe show great differences between the old and the new. Cathedrals built during the Middle Ages stand near American-style supermarkets and glass-and-steel skyscrapers. Ruins of buildings built before the time of Christ still stand in such cities as Athens and Rome. People in some European cities worship in churches that were built before Christopher Columbus landed in America. But modern apartment buildings and department stores, quick-lunch counters, and hamburger stands have become common sights. Automobiles, frozen foods, and television sets are more common in western Europe's cities today than ever before. People speak of the "Americanization of Europe" because, in part, of the resemblance between the modern features of western European cities and those of American cities.

In the countries of eastern Europe, industry developed less rapidly than in western Europe. As a result, the standards of living in eastern European cities are low, compared to the standards of living in the cities of western Europe.

Rural life varies throughout Europe. But rural people generally have a lower standard of living and follow a more traditional way of life than do urban people.

Some farmers in western Europe live on their farms.

But most of them live in villages and travel to their fields each day. Farmers in the northern regions, including Britain and the Netherlands, generally use advanced agricultural methods and equipment. As a result, they have generally achieved the highest standards of living of any European farmers. In parts of southern Europe, especially in Greece and Portugal, some farmers work in much the same way as their ancestors did hundreds of years ago. They use old-fashioned agricultural methods and equipment. But even in such regions, more and more farmers have begun to use modern machinery and methods. On a typical family-owned farm in western Europe, the father, mother, and children provide most of the labor.

When the nations of eastern Europe were under Communist rule, most of the rural people lived and worked on huge farms owned by the government. On some of these farms, called *state farms,* the people worked as government employees. On others, called *collective farms,* the farmers rented or bought their equipment from the government. The government set goals for production.

After the collapse of Communism in the late 1980's, eastern European countries passed laws to allow state-owned land to be redistributed to private farmers. A few government-owned farms still exist in most eastern European countries, but the number of private farms has greatly increased. Some large farms were broken up and sold to individual farmers. Others are now owned and operated as companies by managers and farmers who own stock in them.

The family has held an important place in European life for hundreds of years. Most Europeans think of the family as the most important unit of society because it protects the individual and teaches the person about life. Many Europeans owe their first loyalty to the family. The home has special importance as the center of family life. But commitment to the family is not as strong among young Europeans as it is among older people.

Family ties remain strongest today in the Roman Catholic and Eastern Orthodox countries—such as Greece, Italy, and Spain—and in the nations of eastern Europe. Most of these countries also have the least industrialized and urbanized societies of Europe. The role of the family has become less important in the northern regions of western Europe, which generally are more urban and mostly Protestant.

Social class. Conflict among social classes has played an important part in Europe's history. Feelings of hostility and suspicion between the various classes continue today. In western Europe, the workers, farmers, landowners, and industrialists all are conscious of their class position in comparison to that of other people. Workers and farmers in most countries have had the right to vote and to organize labor unions only since the late 1800's. The poorer classes increased their power during the 1900's. But even today, many children of working-class families do not get a university education or obtain jobs in the professions or in government service.

Under Communism, the nations of eastern Europe probably had less class discrimination than did those of western Europe. The families of officials generally enjoyed more favorable circumstances than other people. But the majority of people had an equal chance to receive both an education and a job. After the collapse of Communism, new class divisions began to form. Some people became more successful than others in competing under the new economic conditions.

The role of government. European governments play a major part in running the economies of their nations and providing for the welfare of the people. Most of the economies of western Europe combine free enterprise and government management. In almost all western European countries, the government is a part or sole owner and operator of such public service businesses as airlines, electric companies, railroads, and

Rus Arnold

Well-stocked stores, like the German butcher shop shown here, are common in western Europe. Stores in these countries carry a wide variety of foods, clothing, and other goods.

© Vince Streano, The Stock Market

Crowded streets are common in European cities. Many cities—such as London with its double-decker buses, *shown here*—have extensive public transportation systems.

telephone companies. In most of these countries, the government also provides many types of social welfare programs. For example, the Swedish government gives every family an allowance for each child under 16 years of age. At least some such programs are common in all major western European nations except Greece and the Netherlands.

Under Communism, the governments of eastern Europe organized and controlled almost all economic activities. In addition, they controlled many areas of people's lives—including their choice of homes and jobs in many cases. With the democratic reforms of the late 1980's and early 1990's, the governments of eastern Europe began to allow more free enterprise and to loosen their control over people's lives.

Languages. About 50 languages and more than a hundred *dialects* (local forms of languages) are spoken in Europe. Languages have been a cause of both division and unity throughout the continent. People generally feel a sense of unity with others in their language group and feel separated from people who speak other languages.

Many experts group the languages of the world into nine major language families. Almost all of the Europeans speak languages that belong to the Indo-European language family, the largest of the families. No one knows where the first Indo-European languages originated, but they probably began in the area north of the Black Sea.

The Indo-European family of languages has three major branches in Europe: Balto-Slavic, Germanic, and Romance. Most people in eastern Europe speak Balto-Slavic languages, which include Bulgarian, Czech, Polish, and Russian. The Germanic languages—such as Danish, English, German, and Swedish—are spoken chiefly in the northern part of western Europe. The Romance languages, spoken mostly in the southern nations of western Europe, include French, Italian, and Spanish. The map in this section shows where many of the European languages are spoken. See also **Language** (Language families; chart; map).

The languages of Europe

This map shows where the major European languages are spoken. Most Europeans speak languages of the Indo-European family, which has three major European branches: Balto-Slavic, Germanic, and Romance.

WORLD BOOK map

Religions. Christianity is by far the major religion in Europe. Christianity began in southwestern Asia, but it developed in Europe and became the world's most widely followed and most influential religion.

Most of Europe's Christians are Roman Catholics. The Catholics live chiefly in the southern regions of western Europe and the northern regions of eastern Europe. Europe's other Christians are about evenly divided between the Eastern Orthodox and Protestant faiths. Members of the Eastern Orthodox Churches live chiefly in Greece, Russia, and in the southern nations of eastern Europe. Protestantism is the chief religion in most northern countries of western Europe. Europe also has several million Jews and Muslims. Jews live in most parts of the continent. The Muslims live chiefly in southeastern European countries, such as Albania and Bosnia-Herzegovina, and in Azerbaijan, Kazakhstan, and Turkey, which are partly in Europe but mostly in Asia.

Under Communism, the governments of the nations of eastern Europe discouraged belief in religion and often persecuted religious groups. But millions of eastern Europeans continued to practice a religion in spite of government opposition. Democratic reforms in eastern Europe in the late 1980's and early 1990's allowed for freedom of religion.

Christianity has played an important part in the history of Europe. Scholars believe that the influence of Christianity—especially Protestantism—was one of the reasons western Europe advanced so rapidly in economic, political, and scientific developments. The teachings of Christianity include belief in the importance of the individual, belief in reason and science, and belief that people can and should learn to master the natural world. Many of these ideas originated in the ancient Greek, Jewish, and Roman civilizations. However, they influenced Europe chiefly because they became part of Christianity.

Many problems have also been caused in the name of Christianity. Much of the violence and bloodshed in Europe have resulted from religious conflict. The Roman Catholic Church, which dominated Europe during the Middle Ages, persecuted nonbelievers and conducted wars known as the *Crusades* against the Muslims.

The birth of Protestantism in the early 1500's led to more than 100 years of warfare between Catholics and Protestants in Europe. Bitterness between Catholics and

Protestants still exists in a few parts of Europe today. For example, disputes between Catholics and Protestants living in Northern Ireland led to much violence in the last half of the 1900's.

Education. As a group, Europeans rank among the best-educated people in the world. The vast majority of them are *literate* (able to read and write). In fact, in almost all of the nations of Europe, 90 percent or more of the people can read and write.

Education in Europe varies from country to country. In Portugal, for example, children must attend school for only six years. But Belgian children must go to school for at least 12 years. France has a highly centralized educational system that is controlled by the national government. Education in Switzerland is directed chiefly by the state governments.

In most northern nations—such as Britain, Norway, and Sweden—most children receive the same education until they are about 15 or 16 years old. At that age, some young people may quit school or begin to attend vocational schools. Others may continue their academic studies to prepare for college.

In general, the quality of education in Europe is higher in the north than in the southernmost regions. Such southern nations as Greece, Portugal, Bulgaria, and Albania are poorer than the northern countries. As a result, they cannot afford to constantly improve their educational programs. On the average, children in these nations attend school for fewer years than do children in the north. They also receive less scientific and technical training. The Roman Catholic Church has had much influence on education in a number of countries in southern Europe.

Until the late 1980's, Communist governments controlled the educational systems in the countries of eastern Europe. Schools taught Communist ideals, and religious instruction was forbidden in most places. Today, most eastern European governments still largely control the educational systems. However, some countries have made control less centralized, and private schools have been established.

Since the democratic reforms of the late 1980's, eastern European schools no longer teach Communist ideals. To try to help their nations develop economically and technologically, eastern European countries have continued to emphasize scientific and technical subjects in their school curriculums. Children who live in these countries must attend school for at least 8 to 10 years.

Europe has many of the world's oldest and most respected universities. These schools include the British universities in Cambridge, Edinburgh, London, and Oxford. They also include Jagiellonian University in Kraków, Poland, and the universities of Bologna, Italy; Dublin, Ireland; Heidelberg, Germany; Moscow; Paris; Rome; and Vienna, Austria.

In addition, Europe has some of the world's leading libraries. These libraries include the Bibliothèque Nationale de France in Paris; the British Library in London; the Bodleian Library of Oxford University in Oxford, England; the Russian State Library in Moscow; and the Vatican Library in Vatican City. For more information on libraries in Europe, see Library (Libraries of the world).

Gordon Gahan

Roman Catholics have made up the largest religious group in Europe for hundreds of years. The Catholics have built many beautiful churches, like the one in Paris shown here.

Adam Woolfitt, Woodfin Camp, Inc.

Oxford University, founded in England in the 1100's, is one of several European universities that date from the Middle Ages. The modern university developed from those medieval schools.

The arts

European art has had greater worldwide influence than the art of any other continent. This influence began after the Middle Ages as the nations of western Europe became the leading world powers. It had the greatest effect on such countries as Canada and the United States that were founded by European immigrants. But European art also reached the parts of Africa and Asia that became European colonies. This influence declined in the 1900's as the power of Europe declined.

This section describes briefly the major historical developments in European art. For more information, see **Architecture; Ballet; Classical music; Dance; Drama; Opera; Painting; Sculpture.**

Ancient Greek and Roman art. The Greeks created the most enduring art of ancient times. Their work influenced European artists for more than 2,000 years. The Greeks were especially skilled in architecture, literature, and sculpture. Greek temples and public buildings, designed with huge, graceful columns, rank among the world's most beautiful structures. The Greeks wrote the first literature of Europe and developed drama as we know it. Greek sculptors created beautiful human figures in bronze and marble.

The Romans based most of their art on Greek art. They made their most important contributions to the arts in architecture, literature, and the development of realistic portrait sculpture. Roman architects developed the use of the arch and concrete, which enabled them to build larger structures than the Greeks built.

Medieval art. The greatest influence on European art during the Middle Ages came from the Christian church. A second important influence—especially in southeastern Europe—was Byzantine art. Byzantine art, in turn, was affected greatly by Eastern Orthodox beliefs and Asian cultures. A third influence on medieval European art was the Islamic art of the Muslims. This influence was felt chiefly in Spain, but it was also felt in southeastern Europe.

Medieval artists dealt mostly with religious themes. The most notable works of art from the period are church architecture, religious paintings, and sculpture.

In the 1000's and 1100's, an artistic style that became known as *Romanesque* achieved its greatest importance. The chief features of Romanesque architecture were its strength and its heaviness. Almost all buildings constructed in the Romanesque style had thick walls, heavy supports, and low, wide arches. Romanesque paintings were colorful, but they did not portray realistic spaces or shapes.

In the 1200's, *Gothic* art became the major style throughout much of Europe. The Gothic style is represented chiefly by works of architecture. Gothic architects designed tall, graceful buildings—especially churches— that did not need thick stone walls for support. Common features of the Gothic style included pointed arches and the substitution of stained-glass windows for large portions of the walls.

Renaissance art began in Italy during the early 1300's and spread through most of Europe during the 1400's and 1500's. Renaissance art was influenced chiefly by the art and philosophy of ancient Greece and Rome. Renaissance artists emphasized the importance of the individual. They also represented shapes and spaces more accurately than had been common during the Middle Ages.

During the Renaissance, artists continued to work with religious themes, but they also began to deal more

Mary Norton

The Chartres Cathedral in France is an example of Gothic architecture, which flourished in medieval Europe.

The Discus Thrower, a Roman copy of a marble statue (400's B.C.) by the Greek sculptor Myron; Ronald Sheridan

Ancient Roman sculpture was based on Greek art. Figures were lifelike and often sculpted in athletic poses.

Oil painting on wood panel (1506); Museum of Art History, Vienna, Austria

Renaissance painting emphasized lifelike figures and realistic settings. Raphael's *Madonna of the Meadow, shown here,* illustrates the Italian artist's skill at portraying beauty and gentleness.

David Moore, Black Star

Ancient Greek drama was the first drama of the Western world. It was performed in theaters like the one in Athens shown here. The lighted temple in the background is the Parthenon.

with everyday subjects. Painters created portraits and pictures of landscapes and street scenes. Architects began to take as much interest in designing houses and public buildings as they did in designing churches, and sculptors portrayed the human body more accurately than ever before.

Art since the Renaissance has reflected the many rapid changes in European society. A number of different styles have developed in the arts. In addition, two new art forms—opera and symphony—were developed in Europe. Opera was first composed and performed in the 1590's. Symphonic music was first composed during the 1700's.

In the 1600's, the rise of nationalism and the conflict between the Protestant and Roman Catholic churches in Europe led to the development of an artistic style known as *baroque.* Political leaders and leaders of the Catholic Church wanted to use art to influence the way people thought. As a result, artists created the emotional and dramatic baroque style.

Since the 1700's, rapid industrial and urban growth, together with great advances in science and technology, have changed European society and created many social problems. Artists have dealt less with religious themes and more with humanity's place in the modern world. During the late 1700's and early 1800's, for example, artists of a movement known as *romanticism* protested against the increasingly mechanized and standardized character of society. They also objected to the social injustices and political tyranny of the time. These artists turned to nature, fantasy, and stories of faraway places to escape from their world, and they emphasized emotion and imagination in their work.

An artistic movement called *realism* developed in the mid-1800's. Artists of this movement tried to portray life as it really was. Realism developed in part because of a new emphasis on detailed reporting that grew out of modern science. It also was influenced by increased interest in understanding the problems of society.

Since 1900, new artistic styles have frequently appeared in Europe. Painters and sculptors have been less concerned with telling a story or dealing with recognizable subject matter than with the overall visual impact of their work. Painters have developed abstract styles that do not show actual objects or figures, but emphasize a feeling, an idea, or a mood. Sculptors have worked with new forms and new materials, such as aluminum and plastics. They have dealt less with the human figure and more with machines and other objects. In architecture, the Bauhaus school of design in Germany created simple, functional, unornamented styles. The Bauhaus has influenced many aspects of modern art, such as the design of buildings and furniture (see **Bauhaus**). Ballet, dancing, drama, literature, and music have shown similar developments as artists have produced works radically different from any previous styles.

The land

Europe covers 4,015,000 square miles (10,398,000 square kilometers), or about one-fifteenth of the world's land area. It is smaller than every other continent except Australia.

The Atlantic Ocean forms the western boundary of Europe. The Ural Mountains, the Ural River, and the Caspian Sea form the eastern boundary of the continent. Europe extends from the Arctic Ocean in the north to the Mediterranean Sea, the Black Sea, and the Caucasus Mountains in the south. Geographers consider Iceland, Great Britain, Ireland, and thousands of other islands that lie off the European mainland to be part of the continent.

Europe is a huge peninsula that extends westward from northwestern Asia. No body of water separates these two continents completely, and so some geogra-

Adam Woolfitt, Woodfin Camp, Inc.

The Northwest Mountains region covers much of northwestern Europe. Many beautiful lakes, including Scotland's Loch Tay, *shown here,* lie in this mountainous region.

H. Herfort, Bruce Coleman Inc.

The Alpine Mountain System covers much of southern Europe. Beautiful scenes like the one in southern Germany shown here help make the region a popular vacationland.

Editorial Photocolor Archives

The Central Uplands region extends from Portugal to the Czech Republic. It is made up of low mountains and plateaus. The Meseta plateau, *shown here,* lies in Spain and Portugal.

Sven-Erik Hedin from Carl Östman

The Great European Plain stretches from the Atlantic Ocean to the Ural Mountains. It has most of Europe's best agricultural areas, including farmland in Ukraine, *shown here.*

phers consider them to be one continent, which they call *Eurasia.*

Land regions

Europe has four major land regions: (1) the Northwest Mountains, (2) the Great European Plain, (3) the Central Uplands, and (4) the Alpine Mountain System.

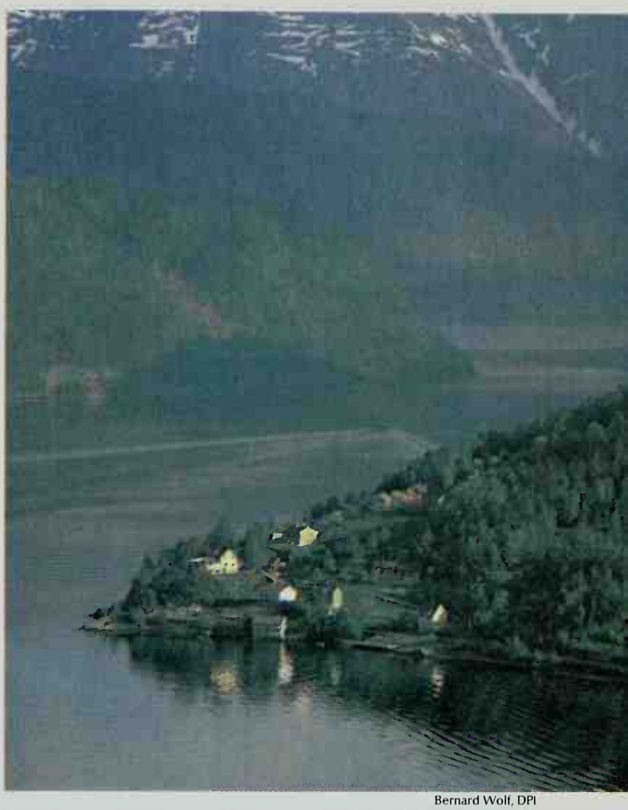
The Northwest Mountains region runs through northwestern France, Ireland, northern Britain, Norway, Sweden, northern Finland, and the northwest corner of the European part of Russia. Mountains cover most of the region. The mountains include some of the oldest rock formations on earth. They have worn down over the years so even the highest peak, Galdhøpiggen in Norway, rises only 8,100 feet (2,469 meters). The thin soil and steep slopes of the mountains make them poor for farming. Large parts of the thinly populated Northwest Mountains region have fewer than 25 people per square mile (10 people per square kilometer).

The Great European Plain covers almost all of the European part of Russia and extends from Russia to France. The region also includes part of southeastern England. In Russia, it extends from the Arctic Ocean in the north to the Caucasus Mountains in the south—more than 1,500 miles (2,410 kilometers). The plain narrows as it stretches through Poland and Germany. It widens in western France. At its narrowest point, in Belgium, it is only about 50 miles (80 kilometers) wide.

The Great European Plain consists chiefly of flat and rolling land and some hills. It has some of the world's most fertile farmland. The western part of the region includes some of the world's most densely populated areas. But in most of the Russian part, the population density is about 70 people per square mile (30 people per square kilometer). The plain averages about 600 feet (180 meters) above sea level in Russia, and less than 500 feet (150 meters) elsewhere.

The Central Uplands region includes low mountains and high plateaus that extend through the central part of Europe. They vary in elevation from about 1,000 to 6,000 feet (300 to 1,800 meters). The uplands include the *Meseta,* or central plateau, of Portugal and Spain; the *Massif Central,* or central highlands, of France; and the plateaus and low mountains of central Germany and most of the Czech Republic. Some parts of the Central Uplands have forests. Most of the land is rocky and has poor soil for farming. River valleys provide the best farmland in these regions. Parts of the Central Uplands—especially in Germany and the Czech Republic—have rich deposits of minerals. Population density in the region ranges from under 125 people per square mile (48 people per square kilometer) in Spain and France to two to four times that many people in parts of Germany and the Czech Republic.

The Alpine Mountain System runs across southern Europe from Spain to the Caspian Sea. This region includes several mountain chains. The Sierra Nevada rise in Spain, and the Pyrenees form the boundary between Spain and France. The world-famous Alps cover part of southeastern France and northern Italy, most of Switzerland, and part of southern Germany, Austria, and northern Slovenia. The Apennines, south of the Alps, cover



Bernard Wolf, DPI

Fiords are long, narrow inlets of the sea that cut into the Norwegian coast. Steep, wooded mountains line most fiords, creating beautiful scenes. Many tiny villages lie along the banks.

much of Italy. Farther east, the Alpine Mountain System includes the Dinaric Alps of Croatia, Bosnia-Herzegovina, and Yugoslavia; the Balkans of Bulgaria; and the Carpathians, which run through northern Slovakia, southern Poland, far western Ukraine, and Romania. The Caucasus Mountains lie at the eastern end of the region.

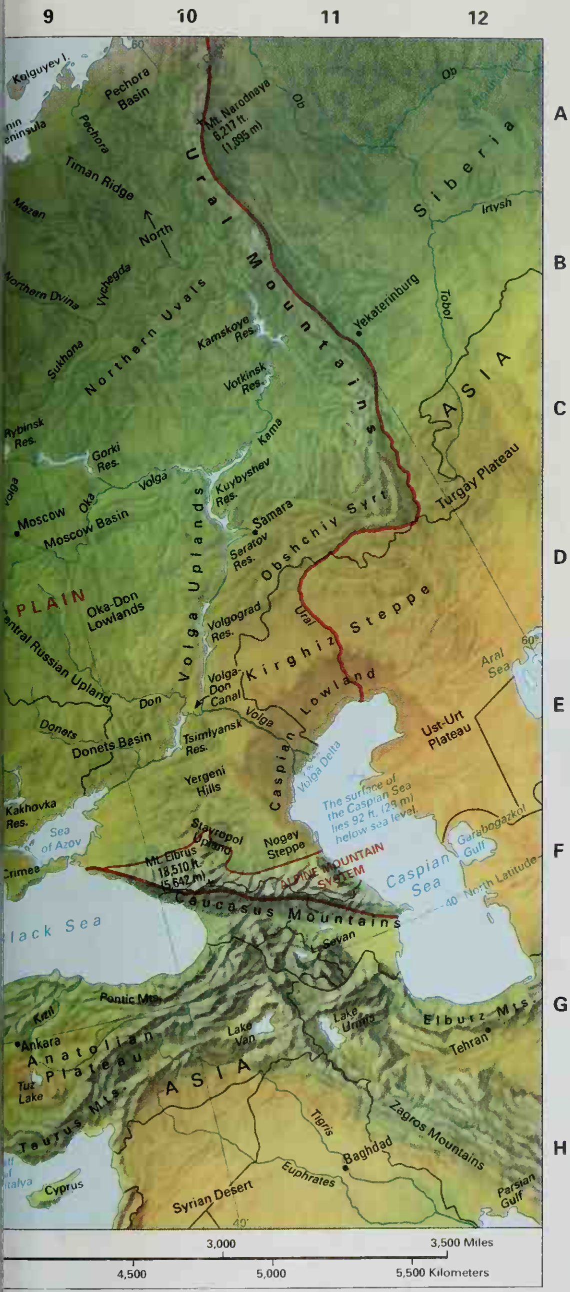
The Alpine Mountain System includes the highest and some of the most beautiful mountains in Europe. The highest peak, Mount Elbrus, rises 18,510 feet (5,642 meters) above sea level in the Caucasus Mountains. Many parts of the region, especially the Swiss Alps, are popular vacationlands. The lower mountain slopes and the broad plains and wide valleys enclosed by some of the mountain ranges provide the best farmland. Heavy forests cover many of the higher slopes. Meadows above the timber line are used as pastureland. Population density in this region varies from an average of less than 25 persons per square mile (10 persons per square kilometer) in some areas to more than 250 persons per square mile (97 persons per square kilometer) in others.

Physical features

Coastline and islands. Europe has a highly irregular coastline. The land curves in and out in a series of large and small peninsulas. The major European peninsulas

Physical features

Adriatic Sea	G	6
Aegean Sea	G	7
Alps (mountains)	F	5
Apennine Peninsula	G	6
Apennines (mountains)	G	5
Balearic Islands	G	4
Balkan Mountains	G	7
Balkan Peninsula	G	7
Baltic Sea	D	6
Barents Sea	A	8
Bay of Biscay	F	3
Black Sea	G	9
Bosporous (strait)	G	8
British Isles	D	3
Cantabrian Mountains	F	3
Carpathian Mountains	F	7
Caspian Sea	F	11
Caucasus Mountains	F	10
Celtic Sea	D	3
Channel Islands	E	3
Corsica (island)	G	5
Crete (island)	H	7
Dal River	C	6
Danube River	F	6
Dardanelles (strait)	G	8
Dnepr River	E	8
Dnestr River	F	8
Dodecanese Islands	H	8
Don River	E	10
Donats River	E	9
Elbe River	E	6
English Channel	E	3
Faroe Islands	B	4
Firth of Forth	D	4
Galdhøpiggen (mountain)	C	5
Gerlachevsky Stit (mountain)	E	7
Gulf of Bothnia	B	7
Gulf of Cádiz	G	2
Gulf of Lion	G	4
Gulf of Riga	D	7
Gulf of Taranto	G	6
Gulf of Venice	F	5
Hebrides (islands)	C	3
Iberian Peninsula	G	2
Iceland (island)	A	3
Ionian Sea	H	6
Irish Sea	D	3
Jutland (peninsula)	D	5
Khalkidhiki Peninsula	G	7
Kola Peninsula	A	8
Lake Geneva	F	5
Lake Ladoga	C	8
Lake Onega	C	8
Lake Peipus	D	7
Land's End (point)	E	3
Lapland	B	7
Ligurian Sea	G	5
Lofoten Islands	A	6
Loire River	F	4
Malta (island)	H	5
Matterhorn (mountain)	F	5
Mediterranean Sea	H	5
Minch, The (strait)	C	4
Mont Blanc	F	4
Mount Elbrus	F	10
Mount Etna (volcano)	H	6
Mount Narodnaya	A	10
Mount Olympus	G	7
Mount Vesuvius (volcano)	G	6
Neman River	D	7
North Cape	A	7
North Sea	D	5
Northern Dvina River	B	9
Norwegian Sea	B	5
Oder River	E	6
Orkney Islands	C	4
Pechora River	A	9



are the Scandinavian Peninsula (Norway and Sweden), Jutland (Denmark), the Iberian Peninsula (Portugal and Spain), the Apennine Peninsula (Italy), and the Balkan Peninsula (Albania, Bosnia-Herzegovina, Bulgaria, Greece, Macedonia, and parts of Croatia, Slovenia, Turkey, and Yugoslavia). Seas, bays, and gulfs lie between the peninsulas.

Europe's irregular coastline makes it unusually long, about 37,877 miles (60,957 kilometers). The length of Europe's coast equals over one and a half times the distance around the equator. The uneven coast provides natural harbors that have helped some countries become leaders in fishing and shipping. Most of Europe—except for the heart of European Russia—lies within about 300 miles (480 kilometers) of a seacoast.

Thousands of islands lie off the coast of Europe. The largest and most important of these is Great Britain, which lies north and west of the European mainland. Other major islands in this area include Ireland, Iceland, the Faroe Islands, the Shetland Islands, the Orkney Islands, and the Channel Islands. Major islands south of the mainland include, from west to east, the Balearic Islands, Corsica, Sardinia, Sicily, and Crete. Each island or group of islands has a separate article in *World Book.*

Rivers. The many rivers of Europe serve as major industrial transportation routes. They also provide water to irrigate farmland and power to generate electricity.

Europe's longest river, the Volga, flows 2,194 miles (3,531 kilometers) through Russia to the Caspian Sea. Canals link the Volga with the Arctic Ocean, the Baltic Sea, and the Don River. The Don winds through Russia to the Black Sea. The Rhine River flows for 820 miles (1,320 kilometers) from the Alps through western Germany and the Netherlands to the North Sea. It is the backbone of the busiest inland system of waterways in the western part of Europe. The Danube, 1,770 miles (2,850 kilometers) long, is Europe's second longest river. It winds from southern Germany through Austria, Slovakia, Hungary, Yugoslavia, Bulgaria, and Romania to the Black Sea. It is the chief water route in the south-central part of the continent.

Other important European rivers include the Dnepr in Russia, Belarus, and Ukraine; the Northern Dvina in Russia; the Western Dvina in Russia and Latvia; the Oder and Vistula in Poland; the Elbe in the Czech Republic and Germany; the Po in Italy; the Rhône and Seine in France; the Tagus in Spain and Portugal; and the Thames in England. Each river mentioned in this section has a *World Book* article.

Lakes. The world's largest lake, the saltwater Caspian Sea, lies partly in the southeastern corner of Europe and partly in Asia. Although called a sea, the Caspian is really a lake because land completely surrounds it. The Caspian covers 143,250 square miles (371,000 square kilometers). Its northern shore lies 92 feet (28 meters) below sea level. It is Europe's lowest point. See **Caspian Sea**.

The area of freshwater lakes totals only about 53,000 square miles (137,000 square kilometers). The largest is Ladoga, which covers 6,835 square miles (17,703 square kilometers). It lies in the northwestern part of Russia (see **Lake Ladoga**). Finland, which has about 60,000 lakes, is known as the *land of thousands of lakes.*

Climate

Europe has a variety of climates, but most of the continent has mild weather. The large map in this section illustrates the continent's numerous climate patterns. The small maps provide information about temperatures and *precipitation* (rain, melted snow, and other forms of moisture).

Europe generally has milder weather than parts of Asia and North America at the same latitude. For example, Berlin, Germany; Calgary, Canada; and Irkutsk, in the Asian part of Russia, lie at about the same latitude. But January temperatures in Berlin average about 15 °F (8 °C) higher than those in Calgary, and they are almost 40 °F (22 °C) higher than the average temperatures in Irkutsk.

Europe's mild climate is caused by winds that blow across the continent from the Atlantic Ocean. The winds are warmed by the *Gulf Stream,* a powerful ocean current that carries warm water from the Gulf of Mexico to the western coast of Europe. The winds affect most of the continent because no mountain barrier is large

What the climate in Europe is like

Tundra - Always cold, with a brief, chilly summer. Little precipitation in all seasons.

Subarctic - Short, cool summers and long, cold winters. Light to moderate precipitation, mostly in summer.

Humid continental - Mild summers and cold winters. Moderate precipitation in all seasons.

Humid oceanic - Moderately warm summers and generally cool winters. Moderate precipitation in all seasons.

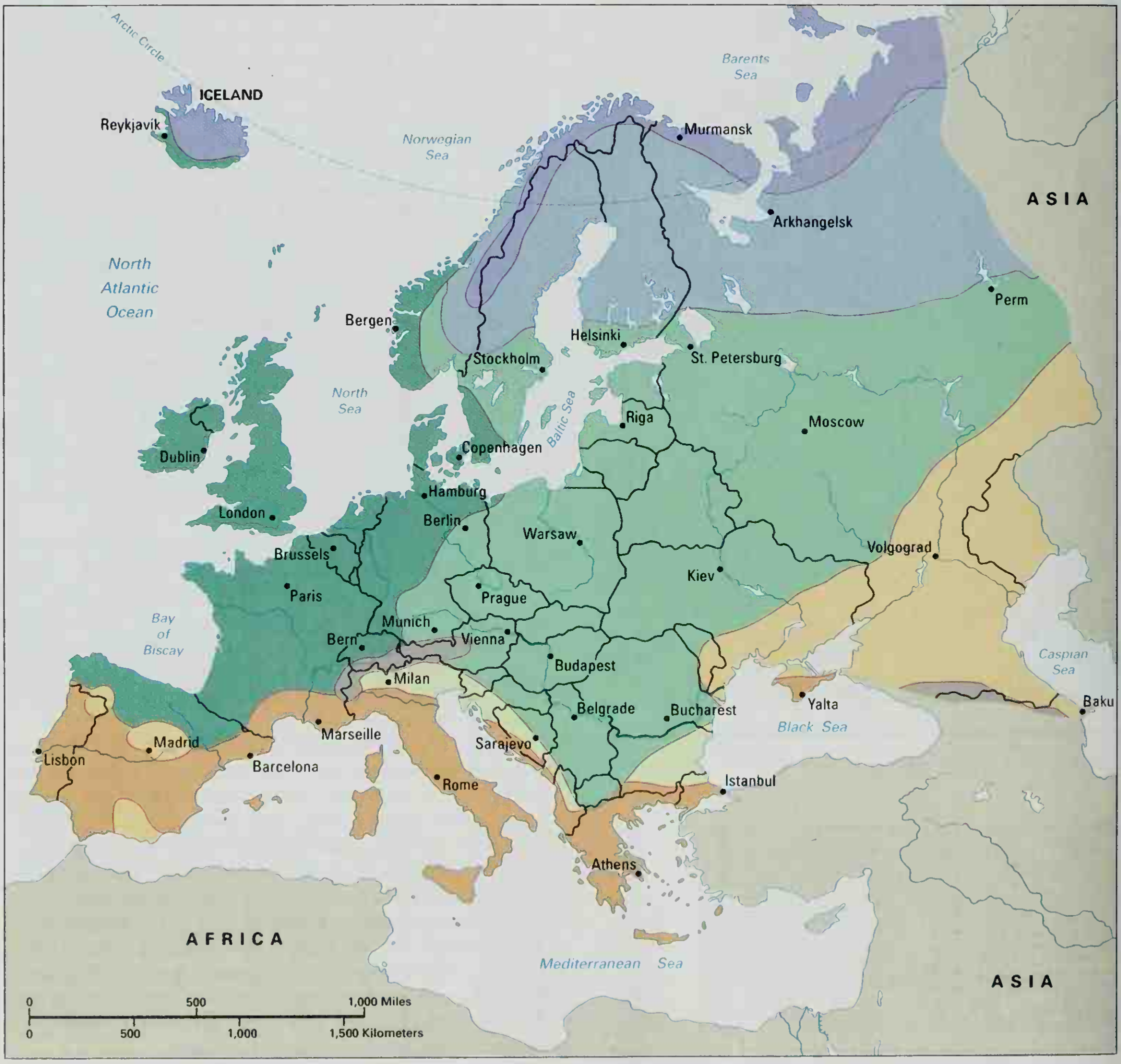
Humid subtropical - Warm to hot summers and cool winters. Moderate precipitation in all seasons.

Subtropical dry summer - Hot, dry summers and mild, rainy winters. Moderate precipitation in winter.

Semiarid - Hot to cold. Great changes in temperature from day to night except in coastal areas. Light precipitation.

Highland - Climate depends on altitude. Climates at various altitudes are like those found in flat terrain.

WORLD BOOK map



enough to block them and because much of Europe is located within 300 miles (480 kilometers) of the Atlantic Ocean.

The most spectacular effect of the Gulf Stream and the strong westerly winds on Europe occurs along the Norwegian coast. Much of Norway's coast lies in the Arctic region, most of which is covered with ice and snow in winter. But almost all of Norway's coast—even that part in the Arctic—remains free of ice and snow throughout the winter.

In general, northern Europe has longer, colder winters and shorter, cooler summers than southern Europe. In addition, winters are longer and colder, and summers shorter and hotter, in the east than in the west. Glasgow, Scotland, for example, has an average temperature of 38 °F (3 °C) in January. But Moscow, which lies at the same latitude, has an average January temperature of 14 °F (−10 °C).

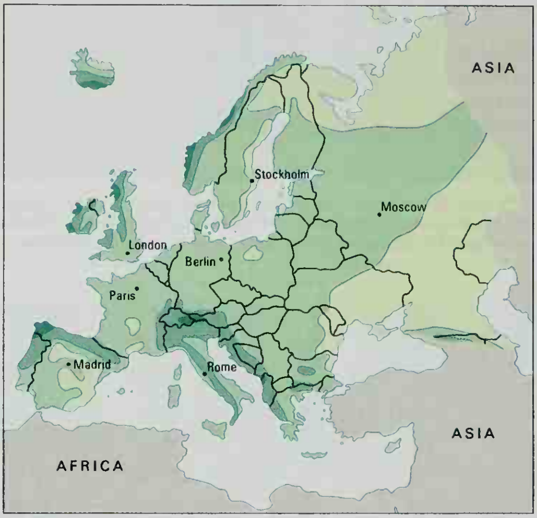
Most of Europe receives from 20 to 60 inches (50 to 150 centimeters) of precipitation each year. The greatest annual precipitation—usually more than 80 inches (200 centimeters)—occurs in areas just west of mountains. Such regions include parts of western England and western Norway. The continent's lightest annual precipitation—usually less than 20 inches (50 centimeters)—occurs in three general areas: (1) east of high mountains, (2) far inland from the Atlantic Ocean, and (3) along the Arctic coast. Such regions include central and southeastern Spain, northern Scandinavia, northern and southeastern parts of European Russia, and western Kazakhstan.

Average yearly precipitation

(Rain, melted snow, and other forms of moisture)

This map shows the average yearly precipitation in Europe. Most of Europe has moderate precipitation.

Inches	Centimeters
More than 60	More than 150
40 to 60	100 to 150
20 to 40	50 to 100
Less than 20	Less than 50



WORLD BOOK maps

Average January temperatures

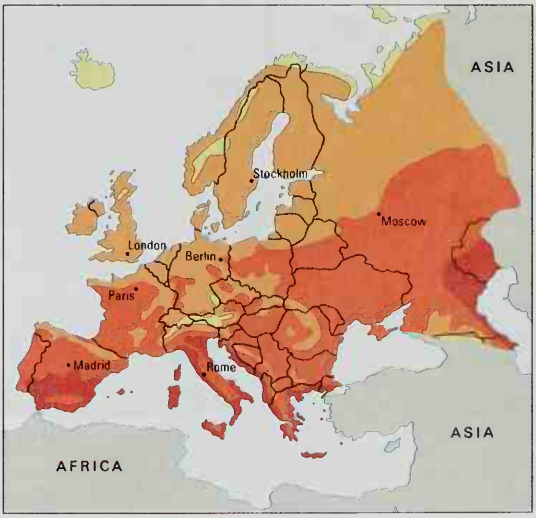
This map shows the range of average January temperatures in Europe. Most of Europe has average temperatures below freezing. The southern and western coastal areas have the warmest winters.

Degrees Fahrenheit	Degrees Celsius
Over 43	Over 6
32 to 43	0 to 6
21 to 32	-6 to 0
Below 21	Below -6

Average July temperatures

This map shows the range of average July temperatures in Europe. Northeastern Europe and the high mountains are the coolest areas, and the Mediterranean and Caspian seacoasts are the warmest.

Degrees Fahrenheit	Degrees Celsius
Over 76	Over 24
65 to 76	18 to 24
54 to 65	12 to 18
Below 54	Below 12



Plant and animal life

Europe's wildlife includes many species of plants and animals that also live on other continents. But some species of wildlife are native only to Europe. These species include a kind of bird called the nightingale and a mammal called the Norway lemming. Europe also has species of wild plants and animals that differ from wildlife of the same name from other continents. For example, the European robin is about half as large as the robin of North America.

Europe's wild plants and animals have been greatly affected by people. Vast forests that once covered much of the continent have been cut down for lumber and to make way for farms and cities. Some species of wild animals have become extinct because of fishing, hunting, trapping, and the expanding human population. Other species of wild animals have nearly vanished. Today, the widespread use of pesticides threatens some species of animals.

Plants in Europe grow in three basic types of areas: (1) forests, (2) grasslands, and (3) tundra and high mountains.

Forests. Most of the forests of central and southern Europe have been cut down, but northern Europe still has large forests. These northern forests are called *needleleaf forests.* They consist mostly of cone-bearing trees called *conifers* or *evergreens.* These trees have narrow, needlelike leaves. Conifers include the fir, larch, pine, and spruce. These trees provide most of Europe's

Plants and animals of Europe

This map shows in general where some of Europe's wild animals live and where some wild plants of Europe grow. Many species of wildlife found in Europe are also native to other continents. But some species, like the nightingale, can be found only in Europe.

WORLD BOOK illustration by John Wood

timber for building and for manufacturing paper. European governments regulate the cutting of these trees to protect the forests.

The central and southern regions of Europe have some *broadleaf forests.* A broadleaf forest consists chiefly of trees with broad, flat leaves that fall off each autumn. Such trees include the ash, beech, birch, elm, maple, and oak. The central and southern regions also have some *mixed forests* of broadleaf and needleleaf trees. In addition, needleleaf forests cover many of the upper slopes of mountains in these regions. *Broadleaf evergreens* are common along the Mediterranean coast. Trees of this type include the cork tree and the olive tree. These trees do not lose their leaves in the fall, and many of them have tough, wax-coated leaves that hold moisture well.

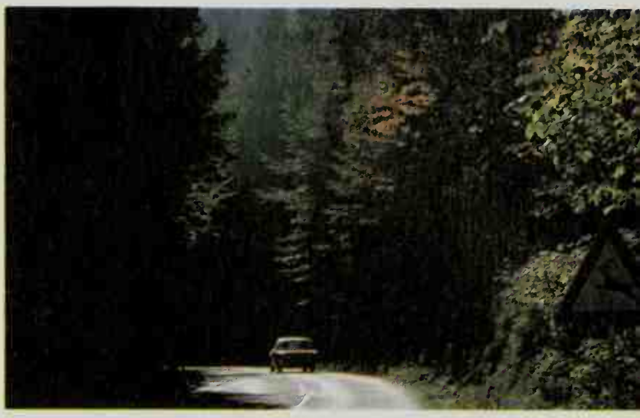
Grasslands are open areas where grasses are the most plentiful plant life. Europe has two types of grasslands—steppes and prairies. Steppes are dry areas where only short grasses grow. Steppes cover most of southwestern Russia and western Kazakhstan. Prairies are fertile areas that have taller grasses than do steppes. Prairies cover much of the central and southern parts of the Great European Plain. Prairies also cover most of the smaller plains of Europe. Farmers use most of the prairies for cropland and grazing land.

Tundra and high mountains are cold, treeless areas. Tundra covers much of the region near Europe's Arctic coast. Land in this region is frozen throughout most of the year. The top 1 to 2 feet (30 to 61 centimeters) of tundra thaws in the short Arctic summer, and many small marshes, ponds, and swamps form on the land. Mosses, small shrubs, wild flowers, and lichens also cover the tundra during the summer season. The upper slopes of Europe's highest mountains resemble tundra. Farmers use parts of the tundra and high mountains as grazing land.

Animals. Most of Europe's wild animals live either in areas that are difficult for people to reach, or in preserves, national parks, or zoos—special areas where people may not kill them.

The European brown bear, one of the largest kinds of bears, lives mostly in Russia and northern Scandinavia. Foxes and wolves roam throughout many regions of Europe. The chamois and ibex, two goatlike animals, live in the high mountains of southwestern Europe. Elk, reindeer, and several other kinds of deer can be found in various parts of Europe from the Mediterranean to the Arctic. Seals live off the Arctic, Atlantic, and Mediterranean coasts. Other wild animals common to Europe include the badger, hare, hedgehog, lemming, mole, otter, rabbit, squirrel, and wild boar. Birds native to Europe include the eagle, falcon, finch, house sparrow, nightingale, owl, raven, robin, stork, thrush, and wood pigeon.

Fish are plentiful in European waters off the Atlantic coast and in the Baltic, Black, Caspian, Mediterranean, and North seas. People who fish for a living catch mostly anchovy, cod, flounder, herring, mackerel, salmon, sardine, sturgeon, trout, and tuna in these areas. In addition, the eggs of sturgeon are used to make a delicacy called *caviar.*



Dennis Brack, Black Star

The Black Forest, in Germany, is made up mostly of dark fir and spruce trees. Forests of such trees are common throughout northern Europe and in mountain areas of southern Europe.

Dan Budnik, Woodfin Camp, Inc.

Reindeer live in far northern Europe. Some wander wild, but the Sami (also called Lapps) herd many reindeer. Sami raise reindeer for food, clothing, and transportation.

J. Zopp from Carl Östman

White storks live in most parts of Europe during the summer. Many nest on chimneys. Europeans protect storks because they kill insects and reptiles.

Economy

The value of Europe's economic production is much greater than that of any other continent. Most European countries have highly developed economies.

Europe's huge output of manufactured goods includes automobiles, machinery, and steel. Service industries, such as banking and health care, are of growing importance. Europe's vast amounts of fertile farmland produce large amounts of wheat and other agricultural goods.

In western Europe, most economic activities operate under private ownership, more or less free from government control. But many enterprises that provide essential goods and services are government-run. These include railroads, banks, and, in some cases, automobile manufacturing. In the late 1980's and the 1990's, many of the governments began selling some state-owned enterprises to private owners.

For many years, eastern European economies were based on the principles of Communism. Under a Communist system, the government has almost total control of the land and the production and distribution of goods and services. In the late 1980's and the 1990's, however, the governments of eastern European nations began taking steps to increase private ownership of economic activities in their countries.

Much trade takes place among European countries. This trade is promoted by several trade organizations. European trade organizations include the European Union and the European Free Trade Association.

Industry

Europe is the birthplace of modern industry. Modern industry began during the Industrial Revolution, which started in Britain in the 1700's and spread to other parts of Europe and to North America in the 1800's.

During the Industrial Revolution, manufacturers began using power-driven machinery to make products. This and other developments greatly increased production and lowered operating costs. The Industrial Revolution helped make several European nations leading industrial centers of the world.

The term *industry* generally includes such activities as construction and mining in addition to manufacturing. But most industrial production by far comes from manufacturing. Europe ranks after the United States as the world's main manufacturing region. The major manufacturing nations of western Europe are the United Kingdom, France, Germany, Italy, the Netherlands, Spain, and Sweden. Major manufacturing nations of eastern Europe include Poland, Russia, and Ukraine.

Most industries in western Europe are privately owned. But in some nations of western Europe, the government owns or controls automobile companies, iron and steel producers, and other major industries. After the economic reforms of the late 1980's, eastern European governments started to sell state industries to allow for free enterprise.

In general, eastern Europe lags behind western Europe in industrial development. In the late 1900's, many European factories closed as a result of strong international competition, and many industries reduced their number of employees.

Manufacturing. Europe produces more manufactured goods than does any other continent. The most highly developed European countries use the latest available technologies to manufacture huge quantities of goods. Numerous European countries also benefit from a skilled labor force. Advanced technology and skilled workers allow Europe to compensate for its lack of raw materials. Only Russia and a few other countries have sufficient amounts of raw materials. Such countries as France and Italy have exhausted almost all of their raw materials. These countries must import such basic materials as iron ore, lumber, and petroleum.

John Launois, Black Star

Coal mining has long been a major industry in Europe. About a fifth of the world's coal comes from the continent. The industry uses modern technology, such as this huge digging machine.

Volkswagenwerk AG

Automobile manufacturing is a leading industry in Germany, *shown here,* and several other European countries. Many of the world's top automobile manufacturing nations are European.

The greatest concentrations of industry in Europe are located chiefly in the continent's leading manufacturing nations. One of the most famous of these industrial centers is the Ruhr in Germany. This region, named for the Ruhr River, developed industries using its high-grade coal deposits. The region's chief industries produce chemicals, iron and steel, machinery, and textiles. The Ruhr region's highly developed transportation network includes railroads and river and canal systems.

European nations rank among the world leaders in the manufacture of many important products. For example, Europe has 6 of the 10 top automobile-producing nations. Automobile manufacturing was a major contributor to the rapid growth of European industry in the last half of the 1900's. Some European automobile companies became world famous. These firms include Fiat, in Italy; Renault, in France; Volkswagen, in Germany; and Volvo, in Sweden.

Mining. Most of Europe's mining takes place in a region that stretches from the United Kingdom to the Caspian Sea. Russia is a leading mining country, and many of its richest material deposits are in Europe.

European mining operations produce about a third of the world's natural gas, a fifth of the world's coal and pe-

Mining and manufacturing in Europe

This map shows the locations of the chief mineral resources of Europe. The most important minerals—such as coal in Russia and bauxite in France—are shown in larger type. The map also shows Europe's major manufacturing centers. The four main industrial areas—the Donets Basin, the Midlands, the Ruhr, and the Urals—are labeled in large red type.

● Coal — Major mineral deposit
• Lead — Other mineral deposit
• Lille — Manufacturing center

WORLD BOOK map

troleum, and a sixth of its iron ore. Europe's richest coal fields lie in Germany, Poland, and Russia. Russia and Ukraine rank among the leading iron ore mining countries. Britain, the Netherlands, and Russia are among the leading producers of natural gas. The chief petroleum producers include Britain, Norway, and Russia. Other important minerals include chromite, lead, manganese, nickel, platinum, potash, silver, and zinc. Most of these minerals are produced primarily in Russia.

Power for European industry comes from many sources, including coal, natural gas, nuclear energy, ocean tides, oil, steam, and water. Coal and *hydroelectricity* (power from water) have long ranked as the chief sources of industrial power in the continent. Europe is the world's chief consumer of coal. Although the continent produces about half of the world's coal, it must still import large amounts. But the use of coal to produce power is decreasing, and the use of natural gas, nuclear energy, and oil is increasing in Europe.

Service industries

Service industries are industries that produce services rather than goods. They include trade, health care, finance, government services, education, transportation, and communications. Service industries grew rapidly in Europe during the last half of the 1900's. Service industries employ more European workers than does any other economic activity category.

Trade. Most of Europe's countries belong to *common markets.* A common market is an economic union of nations. The nations work together to stimulate industrial growth, increase employment, and make more goods and services available to consumers. Common markets stimulate trade among member countries by eliminating tariffs and other trade barriers.

The best-known common market is the European Union. It is based in part on several economic organizations that were founded in the 1950's. In the 1960's, these organizations became known collectively as the European Community. The European Community was incorporated into the European Union when the union was formed in 1993. The union's member nations are Austria, Belgium, Britain, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, and Sweden.

The European Free Trade Association (EFTA), another common market of western European nations, was established in 1960. Its member nations are Iceland, Liechtenstein, Norway, and Switzerland.

In 1949, the Council for Mutual Economic Assistance (COMECON) was founded by countries of eastern Europe. For many years, it was a major trading organization for Communist nations. But in 1991, following the end of Communist rule in many European countries, the council was disbanded.

European countries trade largely within their own common markets but also trade with European countries outside their common markets. Europe's other major trading partners are the United States and Japan. Europe also imports raw materials such as petroleum from the Middle East, and exports finished goods. The continent's major imports are coal, grain, and petroleum. Its major exports are chemicals, clothing and textiles, machinery, motor vehicles, and wine.

Many European countries have high standards of living, and so the people are able to buy large amounts of retail goods. Retail trade employs many of Europe's workers.

Health care. Several of the countries of Europe are centers of research for health care. Britain's Medical Research Council is a government agency that supports biomedical research. The Pasteur Institute in Paris is a world center for the study, prevention, and treatment of disease.

In some European countries, health care is completely *socialized.* Under this system, all medical facilities are publicly owned and all medical personnel are paid from public funds. Citizens receive medical care free or at a low cost.

In some other European countries, medicine is largely socialized. In Britain, for example, the central government owns most of the medical facilities, pays most of the medical personnel, and provides low-cost medical care.

Medicine in most of the countries of western Europe is only partly socialized. The central governments of these countries do not own most medical facilities, nor do they pay most doctors, who are self-employed. But each of these countries has a national health insurance plan that provides free medical care for the very poor or refunds almost all the money a patient spends for medical care. The plan is financed through the social security system in almost all the countries, and it is compulsory for workers who are covered by social security. Doctors who take part in the plan must charge a set fee. Patients generally may choose a doctor and hospital.

In eastern Europe, under Communism, health care was completely socialized. In the mid-1990's, however, private health care services and an insurance system began to be introduced in some of these countries.

Finance is an important industry in the countries of western Europe. For many years, financial activities in eastern Europe were handled by the government. However, since the early 1990's, private and commercial banks have been established in the countries of eastern Europe.

Some of the world's largest banks have headquarters in Britain, France, Germany, and Switzerland. These banks receive much foreign investment because they offer security and a high return on investment.

Major stock exchanges operate in Amsterdam, Frankfurt, London, Paris, and Zurich. The London Stock Exchange serves as the center for the world gold market. London is also the home of the world's most famous insurance society, Lloyd's of London.

Government plays an important role in the economies of European countries. European governments must employ many workers to regulate the economy. Governments also employ people to work in public schools and hospitals and in the military. Europe has many of the world's largest armies.

Transportation. Europe has one of the world's best transportation systems. Networks of airline routes, canals, highways, railroad lines, and rivers crisscross the

continent. They reach most of Europe. All other continents have vast regions that are not served by modern forms of transportation.

A well-developed network of highways and roads serves most of Europe. The ownership of autos among the people of Europe is high by world standards. Trucks carry much of the freight that is transported on the continent. Perhaps the best-known European highways are the German four-lane superhighways that are called *autobahns.*

Europe has about a fourth of the total railroad track in the world. European express trains rank among the best in the world. These trains carry much of the continent's passenger traffic. Inter-City express trains, for example, link principal cities in nine western European countries. Immigration and customs inspectors ride these trains and make examinations during trips. Trains also carry much of the freight shipped in Europe.

Many tunnels carry motor and rail traffic through Europe's mountains. The world's 4 longest motor-traffic tunnels and 5 of the 10 longest railroad tunnels are in Europe. The St. Gotthard Road Tunnel, which cuts through the Alps in central Switzerland, is the world's longest motor-traffic tunnel. The tunnel is 10.1 miles (16.3 kilometers) long. The Simplon Tunnel, one of the world's longest railroad tunnels, links Switzerland with Italy through the Alps. The tunnel is 12.3 miles (19.8 kilometers) long.

In 1986, Britain and France announced plans to construct a railway tunnel under the Strait of Dover, a part of the English Channel. The tunnel opened in 1994. See **Channel Tunnel.**

European airlines fly throughout the continent and the world. The national airlines of Denmark, Norway, and Sweden have been combined to form Scandinavian Airlines (SAS). The Netherlands' Royal Dutch Airlines (KLM), established in 1919, is the oldest airline in the world that is currently in operation. Russia's national airline, Aeroflot, is the largest government-owned airline in the world.

The rivers and canals of Europe form an important transportation system. Barges, boats, and ships carry freight on these waterways.

Europe handles more than half the world's international shipping. Some of the world's largest merchant fleets belong to European countries. Britain, France, Greece, Italy, Norway, and Russia are among the countries that have large merchant fleets.

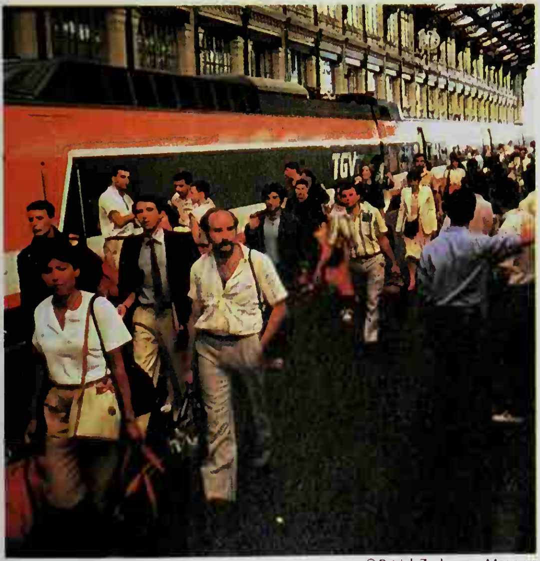
Europe has many important ports. Rotterdam, in the Netherlands, is one of the busiest ports in the world. Europe's other leading ports are Antwerp, Belgium; Genoa, Italy; Le Havre and Marseille, France; and Hamburg, Germany.

Communication. Modern communication systems link almost all parts of Europe with each other and with the other continents. Radio networks broadcast in every European country, and almost all European nations have television networks. A television network called *Eurovision* links the countries of Europe. Mail, telephone, and telegraph services connect all parts of Europe.

Newspapers are published throughout Europe. Some are among the world's most widely read papers. For information on newspapers in Europe, see Newspaper (Newspapers in other countries).

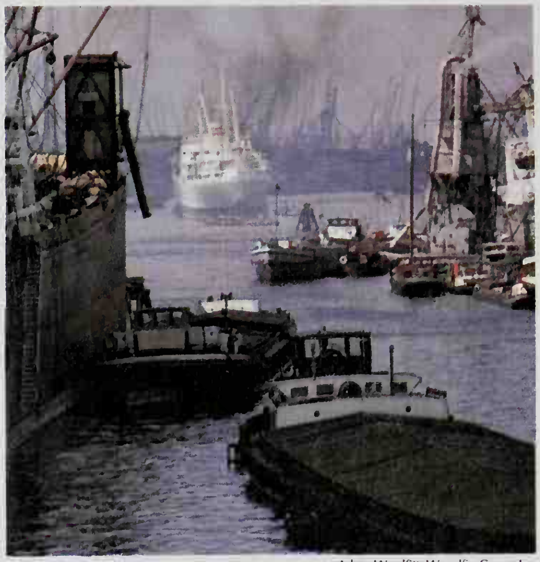
Agriculture

More than half the land in Europe is used for farming. Agriculture employs more European workers than does



© Patrick Zachmann, Magnum

Express trains carry much of the long-distance passenger traffic in Europe. The passengers shown here are leaving a French *TGV (train à grande vitesse,* or high-speed train).



Adam Woolfitt, Woodfin Camp, Inc.

The port of Rotterdam, the Netherlands, *shown here,* ranks as one of the busiest ports in the world. Several other European ports are also leading shipping centers.

any other economic activity. Less than a sixth of the people earn a living from farming.

Europe has some of the world's richest farmland. Farmlands in some parts of Europe—especially western Europe—often produce higher crop yields than farmlands in any other part of the world.

In western Europe and in Russia, Ukraine, and other former Soviet republics, many farmers use advanced scientific techniques. They enrich the soil with chemical fertilizers and plant different crops from year to year to preserve the land's fertility. Large numbers of these farmers also use up-to-date machinery. But in many southern regions of western Europe and in much of eastern Europe outside the former Soviet republics, farmers do not use modern agricultural machinery and methods. As a result, crop yields in those areas generally are lower than in the rest of the continent.

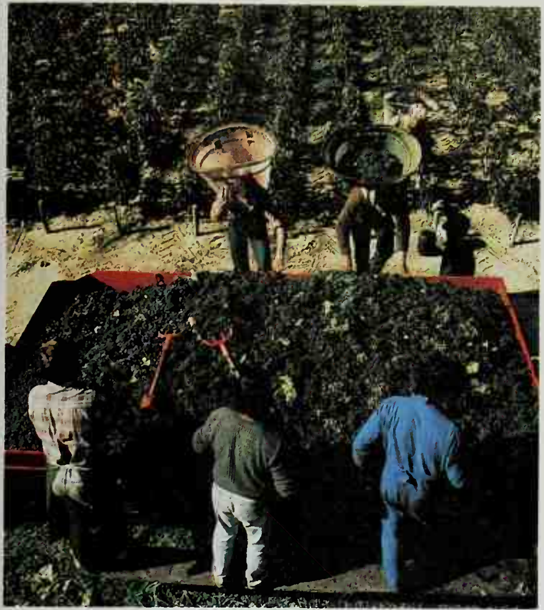
Europeans produce most of their own food. Only about a fifth of the continent's food is imported. Most of the imports consist of tropical goods, such as cocoa and coffee. Many European nations specialize in a few farm products and trade among themselves in order to get

Agriculture and fishing in Europe

This map shows the chief uses of land in Europe. The continent has some of the world's richest farmland, and farmers in western Europe produce some of the highest crop yields. The most important crops—such as wheat in Ukraine and potatoes in Poland—are shown in larger type. The map also shows the major fishing areas in surrounding waters.

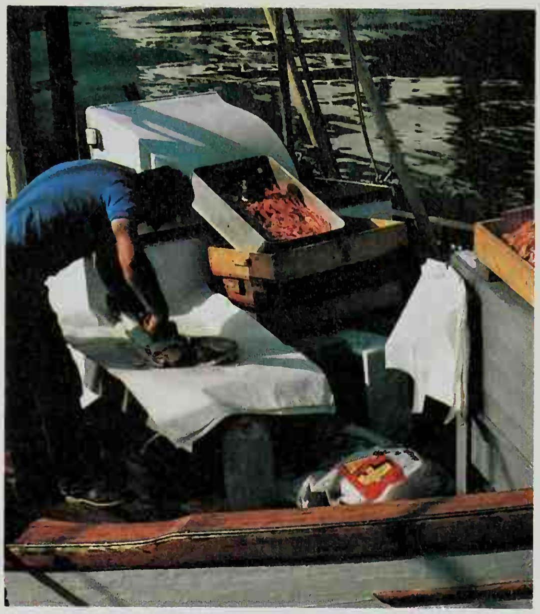
Mostly cropland
Grazing land
Forest land
Generally unproductive land
Major fishing areas

WORLD BOOK map



© Bruno Barbey, Magnum

Grapes from southern France, *shown here,* and other southern regions of Europe are used to make much of the world's wine. Many of the leading wine-producing nations are in Europe.



© Norman Benton from Peter Arnold

Fish processing is an important industry in Norway, *shown here,* and many other European nations. European fishing fleets get about a fourth of the world's fishing catch every year.

the other food they need. The Netherlands, for example, exports many dairy products and imports much of its grain from other European countries.

Farm organization. Almost all the farmland in western Europe is privately owned. Most farmers own the land that they work on. However, in some countries, including Belgium and Britain, as many as half the farmers rent their land from private landowners.

In many western European countries, the farmers have organized farm cooperatives that collect and sell their farm products. Such farm cooperatives help the farmers to reduce their sales costs and to increase their profits. In Denmark and Sweden, some farmers even share their equipment.

For many years, the state owned almost all the farmland in eastern Europe except in Poland and Yugoslavia. The chief types of farms were *collective farms* and *state farms.* On collective farms, the government set production goals. The farmers rented or bought equipment from the government. They received wages and a share of the products and profits. State farms were managed by government officials. Farmworkers received wages but no share of products or profits.

After the collapse of Communism in the late 1980's, eastern European countries returned much of the state-owned land to private farmers. Some state-owned farms were broken up and sold to individuals or to agricultural companies. Some large farms were turned into joint-stock companies. The managers and farmers received stock that made them part owners of the farm and its equipment. They decide what to grow and how to market their products. The government no longer sets production goals or guarantees that it will buy the products. Farmers may receive a small wage and a share of the profits, or they may just receive a share of the profits.

Crops. Europe produces larger crops of barley, oats, potatoes, rye, sugar beets, and wheat than does any other continent. Other important European crops include beans, corn, fiber flax, peas, and tobacco. About half of Europe's cropland is used to grow grain. Wheat, the chief grain crop, grows in most parts of Europe. Nations on the Mediterranean coast produce most of the world's olives. Farmers in these nations also raise citrus fruits, dates, figs, and grapes.

Livestock raising is an important part of farming almost everywhere in Europe. Many farmers raise livestock in addition to producing fruits, grains, and vegetables. Farmers in most parts of Europe raise cattle, hogs, sheep, and poultry for meat. Dairy farming is an important economic activity in such northwestern nations as Britain, Denmark, and the Netherlands. Areas in many of the plain, mountain, and forest regions of Europe are used as grazing land. Some of the world's best breeds of cattle and sheep originated in Europe. Britain has produced many of these breeds, including the Hereford and Jersey cattle and the Hampshire, Shropshire, and Suffolk sheep.

Fishing. The European fishing industry provides an important part of the continent's food supply. Fishing boats sail all the waters that border the continent. However, Europe's most important fishing grounds are located in the North Sea, the Atlantic Ocean, and the Arctic Ocean. In addition, European fishing fleets sail throughout the world and get about a fourth of the world's catch. Norway and Russia are Europe's leading fishing industry nations.

History

Prehistoric times. Scientists have found fossils and stone tools that indicate early human beings lived in Europe more than 700,000 years ago. The best-known forms of prehistoric people in Europe were the Neanderthals and the Cro-Magnon people. Neanderthals lived from about 130,000 years ago to 35,000 years ago. Cro-Magnon people lived from about 40,000 years ago to 10,000 years ago. The Cro-Magnons were an early type of modern human being. The Cro-Magnons lived as hunters, wandering from place to place in search of food. They probably lived in groups that were no larger than 25 to 30 persons.

About 6000 B.C., people in southeastern Europe learned to raise food by farming. This development made it possible for early human beings to take the final steps to civilization. People no longer had to move from place to place in search of food. They could settle in one place and form villages. Some of these villages eventually developed into Europe's first cities. After about 6000 B.C., more and more people in Europe turned to farming for their chief source of food. By the end of prehistoric times—about 3000 B.C.—farming had spread to all parts of Europe except the dense northern forests.

Early civilizations. The first European civilizations developed on islands in the Aegean Sea, east of Greece. Aegean civilization flourished from about 3000 to 1200 B.C. On some Aegean islands, especially on Crete, the people used a system of writing and became skilled architects, craftworkers, and painters. They also were adventurous sailors and traders. A similar civilization developed on the island of Malta, south of Italy. After about 2500 B.C., seafarers from the Aegean islands and Malta sailed along the southern and western coasts of Europe. They introduced their way of life to people they met on the way.

Tribes of horseback riders from the region northeast of the Black Sea swept south and west through Europe around 2000 B.C. These warriors had been herders on the grassy plains of their region. They spread their warrior culture throughout much of Europe as they conquered large numbers of villages.

Ancient Greece made great advancements in the development of civilization. Tribes from the north moved to the Greek Peninsula about 2000 B.C. They developed a way of life based chiefly on the Cretan civilization. The Greeks became the most powerful people in the Aegean area, and, in the 1400's B.C., they took control of the region from the Cretans. During the 1100's B.C., another wave of invading tribes swept into Greece from the north. They conquered most of southern Greece and drove out the people who were living there. During the next several hundred years, groups of these tribes united to form a new type of independent governmental unit. Each of these units was called a *polis,* or city-state. The word *political* comes from this ancient Greek word.

The ancient Greek civilization reached its greatest height during the 400's and 300's B.C. with the rise of Athens, Sparta, and other powerful city-states. The idea of democracy spread during this period, and Greek art and learning flourished. But about the same time, Greece entered a long period of warfare. First, the Greeks defeated attacking forces from the Persian Empire to the east. Then the Greek city-states began to fight among themselves. As this fighting continued, Greece's political strength began to decay. But Athens remained a cultural center of the ancient world.

Macedonia, a kingdom north of Greece, grew stronger during this period, and it seized control of Greece in 338 B.C. Beginning in 336 B.C., Alexander the Great ruled Macedonia. He built a huge empire—partly in Europe but mostly in Asia. Alexander admired the Greeks and spread their culture throughout his empire. Macedonia became weaker after Alexander's death in 323 B.C., but its rulers continued to control Greece.

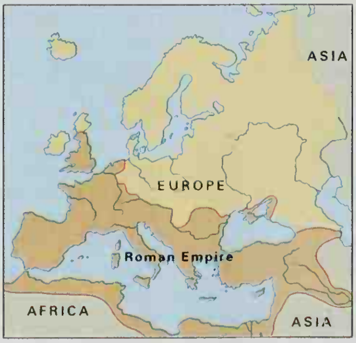
The Roman Empire was the next important ancient European civilization. Historians do not know how or when Rome was founded. But by 275 B.C., it controlled all of the Italian Peninsula south of what is now Florence. In the next 200 years, the Romans built an empire extending from what is now Spain into southwestern Asia and along Africa's northern coast. Later, they added much of the rest of Europe to their empire.

Great European empires, 300's B.C. - A.D. 500's

These maps show the European empires that flourished between the 300's B.C. and the A.D. 500's. The empire of Alexander the Great was the first great empire that began in Europe. It spread Greek civilization into Asia. The maps show each empire at its height.

Alexander's empire, 323 B.C.

Roman Empire, A.D. 117



Byzantine Empire, A.D. 500's

WORLD BOOK maps

Important dates in Europe

c. 3000 B.C. Civilization developed on Crete and other islands in the Aegean Sea.

c. 500 to 300 B.C. Greek civilization reached its height.

27 B.C. to A.D. 180 Rome achieved its greatest power.

A.D. 300's Romans granted the Christians freedom of religion. The Roman Empire split into two parts: the West Roman Empire and the East Roman, or Byzantine, Empire.

400's The West Roman Empire fell, and the Middle Ages began.

732 A Frankish army defeated Muslim forces in Spain.

768-814 Charlemagne built an empire in western Europe.

1054 The Christian Church split into the Roman Catholic Church and the Eastern Orthodox Churches.

1096-1291 Europeans carried on the Crusades.

1347-1352 The Black Death killed about a fourth of Europe's people.

1300's The Renaissance began in Italy.

1500's The Reformation brought Protestantism to Europe.

1689 The English Parliament passed the Bill of Rights.

1789-1799 The French Revolution ended absolute monarchy in France.

1815 Napoleon was defeated in the Battle of Waterloo.

1700's to mid-1800's. The Industrial Revolution swept through Europe.

1914-1918 World War I raged in Europe.

1917 The Bolshevik revolution led to the establishment of a Communist dictatorship in Russia.

1939-1945 The Allies defeated Germany, Italy, and the other Axis powers in World War II.

1940's Soviet-controlled Communist dictatorships seized control of governments in eastern Europe after World War II.

1949 Canada, the United States, and 10 western European nations formed the North Atlantic Treaty Organization.

1950's Western European nations began economic associations that later merged to form the European Community.

1975 Most European nations signed the first of the Helsinki Accords. The signers pledged to work for increased cooperation and to promote human rights.

1989-1990 Most of eastern Europe ended Communist rule and began reforms toward giving the people more freedom.

1990 East and West Germany were unified.

1991 Most of the republics of the Soviet Union declared their independence, and the Soviet Union was dissolved. Three of Yugoslavia's six republics declared their independence.

1993 The European Community was incorporated into a new organization called the European Union. The community's members became the members of the new group. The union was formed to increase economic and political cooperation among the community's members.

1999 The European Economic and Monetary Union, which includes most members of the European Union, began phasing in a common currency, called the euro.

2002 The euro replaced the traditional currencies of many European nations.

Rome reached the height of its power during a time known as the *Pax Romana* (Roman Peace), which lasted from 27 B.C. to A.D. 180. No country was strong enough to threaten the empire during this period, and so the period was a time of peace. Roman art and learning reached a high point, and commerce flourished.

The Romans borrowed many ideas from the Greeks, and they spread much of the Greek culture throughout the empire. In fact, the culture of the Roman Empire is often called *Greco-Roman.* But the Romans also made many contributions of their own to European life. For example, they built carefully planned cities and vast systems of well-constructed roads. Latin, the Roman language, became the basis of the Romance languages spoken in Europe today. Many legal principles developed by the Romans became part of legal systems in Europe and, later, in North and South America.

Christianity began in Palestine, a land in southwestern Asia that was part of the Roman Empire. It soon spread to the European part of the empire. The Romans persecuted the early Christians. But in the early A.D. 300's, the Roman Emperor Constantine the Great granted the Christians freedom of religion. Christianity became the official religion of the empire in the late 300's.

By the late A.D. 100's, powerful tribes from the north and east threatened the Roman Empire. Rome could not defend all of its territory. Disagreement within the empire also posed a threat, and the empire began to break apart. Constantine reunited the empire in 324. But it again began to break apart after his death in 337.

The Roman Empire split permanently into two parts in 395. The eastern half of the empire became the East Roman, or Byzantine, Empire. Constantinople (now Istanbul, Turkey) was its capital. The rest of the empire became the West Roman Empire, with Rome as its capital.

Germanic invasions. Germanic tribes lived throughout Europe north of the West Roman Empire. These tribes included the Angles, Franks, Jutes, Saxons, Vandals, and Visigoths. Some of these peoples adopted the civilization of their Roman neighbors. But most of the tribes were rough, uneducated people whom the Romans called *barbarians.*

During the late 300's and the 400's, Mongolians from central Asia, called *Huns,* attacked the Germanic tribes and drove them into the West Roman Empire. The Vandals moved into what is now Spain, and the Visigoths invaded the Italian Peninsula and looted Rome. The Visigoths then moved westward and eventually defeated the Vandals. The Angles, Jutes, and Saxons invaded Britain, and the Franks conquered most of what is now France. In 476, the German chief Odoacer overthrew the last West Roman emperor, Romulus Augustulus.

At the time the Germanic tribes moved through western Europe, Slavic peoples settled much of eastern Europe. The Slavic tribes lived in peace with the Romans.

The rest of this section tells about the history of non-Russian Europe. For the history of European Russia and the former Soviet Union, see **Russia** (History); **Union of Soviet Socialist Republics** (History).

The Middle Ages was a period in western Europe that began with the fall of the West Roman Empire and lasted through the 1400's. The strong governments established by the Romans disappeared during this period. They were replaced by many small kingdoms and states. The Roman Catholic Church became the most powerful force on the continent, not only in religious matters, but also in politics, learning, and the arts.

Most European trade that had developed under Ro-

man rule collapsed. As a result, people had to depend more and more on farming to make a living. Towns lost their importance as people moved to rural areas. The middle class, which had managed most of the trade and industry, almost disappeared. Such arts as reading and writing were nearly forgotten.

An economic system called *manorialism* gradually developed in medieval Europe. Under this system, farms became part of large estates called *manors,* which were owned by wealthy lords. The land was worked by peasants called serfs. In return for use of the land, the serfs owed many goods and services to the lord. The serfs depended on the lord for protection and what little government he could provide.

The Franks established the most powerful kingdom in medieval Europe. The kingdom included what is now Belgium, France, and the Netherlands, and much of what is now western Germany. It achieved its greatest power under the rule of Charlemagne (Charles the Great), from 768 to 814. Charlemagne built an empire that extended from what is now northeastern Spain north to the Baltic Sea and east onto the Italian Peninsula. He supported the Roman Catholic Church and tried to reestablish the West Roman Empire. The pope crowned him emperor in 800. But his empire broke apart after his death in 814.

In the 900's, Otto I of Germany added territory to his country and took control of the northern half of the Italian Peninsula. The pope crowned Otto emperor in 962, marking the start of what later was called the *Holy Roman Empire.* Otto hoped his empire would become as powerful as Charlemagne's had been. But it began to break apart in the 1000's.

Most of Europe remained poor and thinly populated from the 400's through the 900's. Large areas covered with swamps or thick forests could not be farmed. Disease, famine, war, and a low birth rate kept the population small. People lived an average of only 30 years.

After the fall of the Frankish empire, a military and political system known as *feudalism* developed in much of western Europe. In this system, powerful lords—who owned most of the land—gave some holdings to less wealthy noblemen in return for pledges of allegiance. These lesser nobles, called *vassals,* swore to fight for the lord when he needed their help.

Beginning in the 1000's, the feudal lords established a period of peace and security. Merchants again began to travel the old land routes and waterways of Europe. Towns sprang up along these trade routes. The peasants learned better farming methods and gained new land for farming by clearing forests and draining swamps.

This period of economic growth eventually weakened the manorial and feudal systems and contributed to the rise of great national states in Europe. Towns grew as trade increased, and many peasants left the land to seek jobs in the towns. Others found they could support themselves by farming land near the towns and selling food to the increasing number of townspeople.

In most cases, the middle class that developed in the towns supported the kings against the feudal lords. The townspeople agreed to pay taxes to the king in return for protection and freedom to develop their businesses. The kings became stronger and stronger. They could afford to hire armies, and often could force the feudal lords to accept their authority.

In the early 1300's, wars, disease, and economic problems again disrupted life in western Europe. The end of feudalism led to civil wars as peasants revolted against feudal lords. English and French kings fought for control of France in the Hundred Years' War from 1337 to 1453. This fighting exhausted the economies of both nations and interrupted trade throughout Europe. The *Black Death,* an epidemic of plague, killed about a fourth of Europe's people from 1347 to 1352. Severe droughts and floods caused further difficulties.

The cultural, economic, and political changes of the 1300's began to move western Europe out of the Middle Ages. During this period, scholars and artists became less concerned with *theology* (the study of divine matters). They began to concentrate more on trying to understand language, history, and human nature. Their new view of life became known as *humanism,* and it became the central theme of the Renaissance.

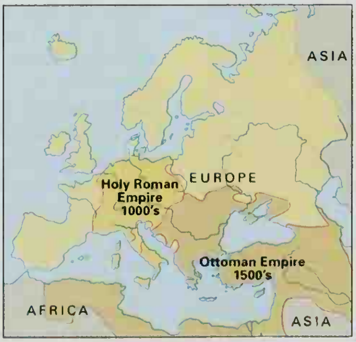
The Byzantine Empire, which was a continuation of the East Roman Empire, lasted through the Middle Ages. In the 500's, it controlled much of southeastern Europe,

Great European empires, A.D. 800 - 1812

These maps show the great empires that flourished in Europe from the time of Charlemagne to that of Napoleon. The Ottoman Empire began in Asia and gained control of a large part of southeastern Europe. The maps show each empire at its height.

Charlemagne's empire, 800

The Holy Roman and Ottoman empires



Napoleon's empire, 1812

WORLD BOOK maps

parts of what are now Italy and Spain, much of the Middle East, and lands along the northern African coast. But by 1400, all that remained of the once mighty empire was the area around its capital, Constantinople.

For hundreds of years, the Byzantine Empire served as a barrier against barbarian attacks and invasion by Muslims from southwestern Asia. It also preserved much of ancient Greek and Roman culture, which western Europe ignored in the Middle Ages. Constantinople became the center of eastern Christendom, and Christianity spread through much of eastern Europe. After the Christian Church split in the 1000's, the Eastern Orthodox Churches developed out of Byzantine Christianity.

Muslim influence. During the early 600's, the Islamic religion emerged in Arabia. By the early 700's, followers of the new religion, who were called *Muslims,* had conquered the Middle East and much of northern Africa. They had also gained a foothold in Europe by conquering Spain. The huge Muslim Empire included more territory than did the Roman Empire. The Muslims who conquered Spain threatened all of western Europe until a Frankish army defeated them in 732. The Muslims remained powerful in Spain until the 1200's.

During the 1000's, Turkish Muslims from central Asia conquered Asia Minor (now Turkey) and the Middle East. Beginning in the 1300's, another Muslim group from central Asia, the Ottomans, gradually took control. By the mid-1500's, the Ottoman Empire included much of the Middle East, northern Africa, and southeastern Europe. The Ottomans held this territory until the 1800's.

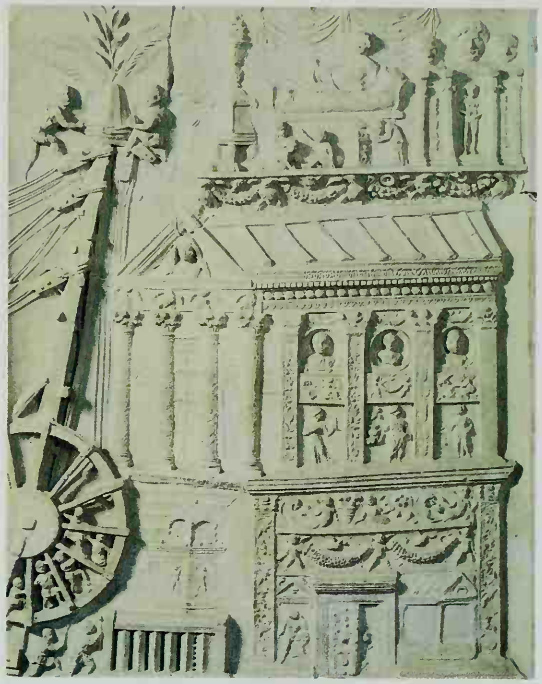
From about 1100 until almost 1300, western European forces conducted a series of military expeditions called the *Crusades* to free Palestine—where Jesus Christ had lived—from Muslim rule. They failed to win permanent control of the Holy Land, but they found they could profit from trading with the Muslims. The Crusades brought about a large increase in the rate of that trade.

The Muslims contributed much to the culture of Europe. They had preserved many ancient Greek writings, and they made the writings available to European scholars. The Muslims also made many advances in the study of mathematics and medicine, and they introduced the system of Arabic numerals, which is used today.

The Renaissance was a 300-year period of great advancement in the arts and learning in Europe. It began in Italy in the early 1300's, during the late Middle Ages, and spread throughout most of Europe during the 1400's and 1500's. The ideals of the Renaissance have had a major influence on Western civilization ever since.

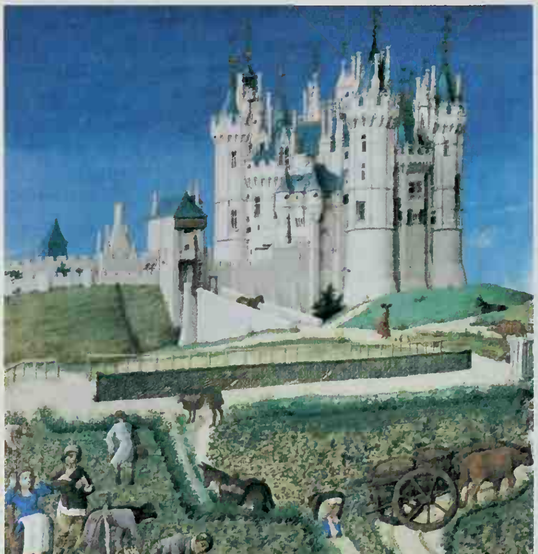
The people of the Renaissance looked back on the earlier Middle Ages as a time of ignorance. They tried to model their lives on the cultures of ancient Greece and Rome and stressed the importance of people. This philosophy contributed greatly to the growth of democracy and a renewed interest in education and scientific research. Johannes Gutenberg, a German goldsmith, invented movable type in Europe about 1440. This contributed to the spread of important ideas.

The Reformation was a religious movement of the 1500's in Europe. It began as an attempt to bring about changes in the Roman Catholic Church. But it led to the birth of Protestantism.



Stone relief (A.D. 200's or 300's) from the tomb of the Haterii family; Museo Gregoriano Profano, Rome (SCALA/Art Resource)

The ancient Romans were skillful builders. They constructed many large buildings throughout their empire. This relief sculpture shows a Roman tomb under construction.



"September" by the Limbourg brothers, from the Duc de Berry's *Très Riches Heures,* an illuminated French manuscript of the 1400's Musée Condé, Chantilly, France (Bibliothèque Nationale, Paris)

During the Middle Ages—the A.D. 400's to the 1500's—wealthy lords owned most of the land in western Europe. They also ruled the peasants who worked in their fields.

Detail of an illuminated French manuscript of the 1500's; Bibliothèque Nationale de France, Paris

During the Renaissance—about 1300 to 1600—movable printing type was invented in Europe. By 1500, Europe had more than a thousand print shops. This picture shows a shop in Paris.

The Roman Catholic Church lost much of its influence in Europe during the 1300's and 1400's. Internal disputes and abuses in certain practices weakened the church. At the same time, many European kings increased their power and challenged the authority of the pope and the Holy Roman emperor. Reform leaders claimed that the church neglected its spiritual responsibilities, and people began to lose confidence in their church leaders.

Several religious reformers in Europe criticized the Roman Catholic Church. But in 1517, Martin Luther, a German monk and theology professor, became the leader of the reform movement. Luther's criticisms gradually led him and his followers to break completely with the Catholic Church. Within 40 years, the Reformation had led to the establishment of Protestant churches in nearly half of Europe. At the same time, this movement was a chief cause of a reform movement known as the *Counter Reformation* in the Catholic Church.

Protestantism became most popular in the northern regions of Europe, while most people in the south remained Catholic. This division and the spread of Protestant beliefs contributed to the start of a series of religious wars between Protestants and Roman Catholics that ended with the Thirty Years' War. From 1618 to 1648, much of Europe was involved in this war.

The rise of the great powers in Europe began during the late Middle Ages. As the power of the feudal lords declined, the kings became stronger. At the same time, the Roman Catholic Church began to lose its influence in European affairs. The religious struggles of the 1500's and 1600's further weakened the Catholic Church, and led the kings to increase their power in order to maintain peace among the people.

By the early 1700's, the processes of war and of state building had given rise to the great powers that were to dominate Europe for the next 200 years. England and France began to become unified, powerful nations during the 1100's and 1200's. Spain and Portugal became the great powers of Europe in the 1400's, but declined in the 1500's. The Netherlands was a top sea power in the 1600's. But wars with England and France between 1652 and 1713 weakened the Netherlands, and Britain and France became the leading European powers. By then, Prussia and Russia also had become strong nations.

During the great age of European exploration, which began in the 1400's, Europe's influence spread around the world. Portuguese and Spanish sailors were the leading European explorers of the 1400's and 1500's. Christopher Columbus, an Italian navigator in the service of Spain, reached America when he sailed from Spain to the West Indies in 1492. In 1497 and 1498, a Portuguese explorer, Vasco da Gama, made the first voyage from Europe around Africa to India. About 20 years later, Ferdinand Magellan, a Portuguese navigator in the service of Spain, led the first European expedition to sail around the world. Sailors from England, France, and the Netherlands also took part in exploration.

During this period, the European powers established colonies in Africa, Asia, and the Americas. Steadily growing trade with these colonies brought more and more wealth and power to the European nations.

The Age of Reason began in the 1600's and lasted until the late 1700's. During this period, most of the leading European thinkers insisted that the use of reason was the best method of learning truth. They questioned traditional beliefs and condemned superstition and the uncritical acceptance of supposedly established facts.

Belief in the power of reason led to the development of the modern scientific method. Scientists applied the reasoning process to their study of the physical world, and they organized general rules for scientific study that are still followed today. They made important discoveries in the fields of anatomy, astronomy, chemistry, and geometry. For example, an Italian astronomer named Galileo discovered that the moon does not shine by its own light. William Harvey, an English physician, showed how blood circulates in the human body. The success of such scientists led Europeans to believe that people could begin to gain control over nature. Such scholars as Thomas Hobbes and John Locke began to apply procedures similar to the scientific method to the study of such subjects as economics, government, and religion.

In the 1700's, in reaction to these developments, people began to value feeling and individuality as well as order and reason. Such thinking helped to bring on the

romantic movement that followed the Age of Reason.

Democracy and nationalism became powerful political forces in Europe during the 1600's and 1700's. The democratic movement grew in large part because of the Age of Reason and its challenge of traditional authority. Nationalism, in turn, developed mostly from the strong feelings that united people of each European country in their fight for democratic government.

In the 1600's, the English people made the most important challenge since the Middle Ages against the power of kings in Europe. Following a civil war, they abolished the monarchy for 10 years in the mid-1600's. In 1689, the English Parliament passed a Bill of Rights that increased its own authority, limited the king's power, and guaranteed the liberty of the people.

The French Revolution, which took place from 1789 to 1799, was the most important democratic revolution in Europe during this period. The laboring poor and most of the educated elite of France revolted against King Louis XVI and seized control of the government. The French National Assembly adopted the Declaration of the Rights of Man and of the Citizen, a document that set forth the principles of human liberty and the rights of individuals. During the revolution, Napoleon Bonaparte rose through the ranks of the French Army. He seized control of the French government in 1799, and the French Revolution ended.

The French Revolution brought France into opposition with the rest of Europe. The monarchs who ruled the other European nations feared the spread of democratic ideals. Under Napoleon's leadership, the French armies at first seemed unbeatable. By 1812, they had conquered most of mainland Europe west of Russia and the Ottoman Empire. But Napoleon lost most of his army that same year when he invaded Russia. Allied European forces defeated Napoleon in 1815 at the Battle of Waterloo and drove him from power. The ideas of the French Revolution continued to spread through Europe.

Europe's political leaders met at the Congress of Vienna in 1814 and 1815. They wanted to restore much of the European political system to the way it had been before the French Revolution. The congress changed the boundaries of many European countries and tried, in the process, to smother the democratic and nationalistic feelings of the people. The congress restored monarchies in France, Spain, and several other countries where they had been removed by Napoleon. In some cases, it joined peoples of different nationalities under a single ruler. But these changes failed to halt the spread of democracy and nationalism in Europe.

Revolutions broke out in many parts of Europe during the 1800's, and many national states were formed. For example, uprisings against the ruling monarchs began in Italy and Spain in 1820 and in Greece in 1821. Democratic revolts took place in Belgium, France, and Poland in the early 1830's. Italy was founded as a national state in 1861 and Germany in 1871. By 1900, nearly every European nation except Russia had a constitution and at least some democratic institutions.

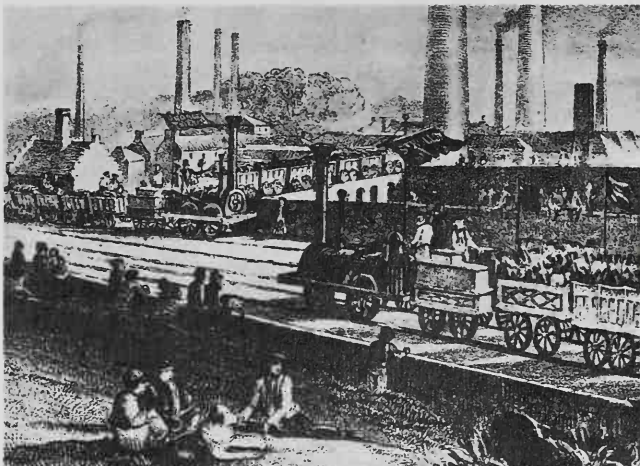
The Industrial Revolution began in Britain during the 1700's. Industry grew rapidly with the development of power-driven machinery and new methods of production. By the mid-1800's, the Industrial Revolution had become widespread in western Europe.

Most Europeans were farmers before the Industrial Revolution. But as factories appeared, towns grew rapidly into industrial cities. People streamed into these cities to take factory jobs. Industrial growth brought many social changes. The middle class of business leaders and industrialists grew rapidly. They owned most of the factories, hired the workers, and operated the banks, mines, railroads, and shops. At the same time, new production methods threatened the occupations of some skilled craftworkers, many women and children began to work outside the home, and unskilled laborers streamed into the cities. Most laborers were poorly paid, and they worked and lived under poor conditions.

During the mid-1800's, Karl Marx, a German social philosopher, developed the theories of Communism. He called for workers to rise up against the wealthy and to establish state-controlled economic systems and classless societies. Marx believed that this type of revolution would occur as a result of industrialization, but it did not take place.

Workers in many countries won the right to form labor unions during the 1800's. Britain and other nations began to pass laws regulating working conditions in factories. Britain and Germany pioneered in adopting social legislation that provided accident, sickness, and unemployment insurance for workers. By the late 1800's, most industrial nations had labor union movements and laws that regulated working conditions.

Colonial expansion by the European powers increased as the Industrial Revolution continued. The industrial nations needed such raw materials as copra and cotton for their factories, and Africa and Asia had great quantities. These continents also provided vast markets where the industrial nations could sell their manufactured goods. Europe's superior weapons made con-



Detail of *Opening of the Glasgow and Garnkirk Railway, 1831,* a lithograph by David Octavius Hill. Science Museum, London

The Industrial Revolution, which began in Britain in the 1700's, led to the first use of steam-powered railroad trains. This picture shows the opening of a railway in Scotland in 1831.

quest easy, and colonies became an area of competition among the European nations. Chiefly for these reasons, the European powers—especially the United Kingdom and France—established many colonies in Africa and Asia. During the 1800's and early 1900's, most of Africa and about a third of Asia became European colonies.

World War I began in Europe in 1914. It resulted chiefly from the competition for colonial and economic power among European nations, the desire of national groups to gain independence, and the secret military alliances among nations of Europe.

The United Kingdom, France, Russia, and other nations (known as the *Allies)* opposed Germany, Austria-Hungary, and their allies (known as the *Central Powers).* The United States joined the Allies in 1917. In November 1917, the Bolshevik revolution in Russia led to the founding of a Communist dictatorship there, and Russia withdrew from the war. The Allies gained victory in 1918. The Treaty of Versailles (1919) marked the war's end.

The war brought many changes of government in Europe. Austria-Hungary, for example, was divided into several national states. Six nations in eastern Europe—Czechoslovakia, Estonia, Latvia, Lithuania, Poland, and what was later Yugoslavia—won their independence. The German monarchy collapsed, and a democratic republic was set up in that country.

Between world wars. The Versailles settlement left many of Europe's problems unsolved and created some new problems. The treaty changed boundaries and formed nations in Europe. It also forced Germany to disarm and make huge payments to the Allies. In the 1920's, German minority groups in many of the newly formed nations demanded that Germany be given control of their territory. Germany's disarmament and payments to the Allies caused the German people to feel that they had been treated too harshly.

The Soviet Union was formed under Russia's leadership in 1922. By the end of the 1920's, Joseph Stalin had become dictator of the Soviet Union. Also in the 1920's, Benito Mussolini established a form of dictatorial rule called *fascism* in Italy. The economic depression that hit Europe in the 1930's helped these men increase their power. In 1933, Adolf Hitler set up the fascist Nazi dictatorship in Germany. The leaders found that millions of people were ready to accept their promises of better living and working conditions.

The Spanish Civil War (1936-1939) was a testing ground for the military might of Hitler, Mussolini, and Stalin. The Soviet Union supported the Spanish Loyalists. Germany and Italy aided the rebel forces of Francisco Franco, which won the war.

World War II began in Europe in 1939 after Germany had gained control of Austria and Czechoslovakia and invaded Poland. The war involved Germany, Italy, Japan, and a few other nations (the *Axis),* against the United Kingdom, France, the Soviet Union, the United States, and more than 40 other countries (known as the *Allies).*

Early in the war, the United Kingdom, France, and their allies tried to halt the German advance through Europe. But by 1941, Hitler and Mussolini occupied or controlled almost all of non-Soviet Europe. That year, Germany invaded the Soviet Union, and Japan attacked the United States at Pearl Harbor in Hawaii.

With the Soviet Union and the United States drawn into the war, the tide of the fighting slowly turned against the Axis powers. Italy fell in 1943, but Germany carried on the war in Europe until its defeat in 1945. World War II killed more people and destroyed more

Europe before World War I

This map shows Europe in 1914, before World War I. By that time, most of the Balkan nations had gained independence from the Ottoman Empire. Other nations had begun to demand independence from Austria-Hungary, Germany, and Russia.

Europe after World War I

This map shows Europe about 1923, after the treaties that ended World War I had taken effect. As a result of those treaties, many central and eastern European nations won their independence from what had been Germany, Russia, and Austria-Hungary.

WORLD BOOK maps

property in Europe than had any other war.

Postwar Europe. World War II brought the downfall of western Europe as the center of world power. The war weakened the major European nations, and these nations lost control of almost all their African and Asian colonies within 15 years. The Soviet Union and the United States emerged as the leading world powers. Soviet-controlled Communist governments seized most of the countries of eastern Europe. Western Europe became economically and militarily dependent upon the United States. Germany became a divided country with a Communist government controlling East Germany and non-Communists governing West Germany.

Disorder and confusion followed the war in Europe. Millions of homeless refugees wandered through the devastated battle areas, and disease and famine spread rapidly. In 1948, the United States set up the European Recovery Program—known as the *Marshall Plan*—to help the nations of western Europe rebuild their economies. Other U.S. assistance programs followed the Marshall Plan. By the early 1950's, most of the nations of western Europe were producing more than they had before the war. The nations of eastern Europe recovered more slowly with Soviet assistance.

The Cold War. Shortly after the end of World War II, Europe became the center of a power struggle between the Communist world, led by the Soviet Union, and the non-Communist world, led by the United States. This struggle, which became known as the *Cold War,* grew more and more intense in the 1950's and early 1960's.

In 1949, the United States and Canada joined with most of the major nations of western Europe to form the North Atlantic Treaty Organization (NATO). This military defense alliance was formed to provide unified military leadership for the common defense of the member nations. In 1955, the Soviet Union and most of the other nations of eastern Europe signed a mutual defense agreement known as the Warsaw Pact. In October 1956, people in Hungry rebelled against the Communist government and took control of the country. Soviet forces entered Hungary in November and crushed the revolt.

The late 1960's and early 1970's saw a gradual relaxation of Cold War tensions. West Germany moved to improve relations with its Communist neighbors. Some eastern European nations began to act more independently of the Soviet Union. Albania left the Soviet camp and sided with China. Romania began to trade with the West, and Czechoslovakia started a reform program to give its people more freedom. But the Soviet Union invaded Czechoslovakia in 1968 and ended the democratic reform movement. This show of force made it clear that the Soviet Union intended to maintain its power in eastern Europe.

Toward European unity. Many nations of western Europe banded together into various organizations during the postwar years. They hoped to solve problems by working together more closely. The Council of Europe was formed in 1949 to link its member nations culturally, socially, and economically. The European Coal and Steel Community (ECSC), organized in 1951, sought to unify the coal, iron, and steel industries of Belgium, France, Italy, Luxembourg, the Netherlands, and West Germany.

United Press Int.

World War II began with the German invasion of Poland on Sept. 1, 1939, *shown here.* The war ended in 1945. It brought great destruction to many European cities and towns.

In 1957, the six ECSC members formed the European Economic Community (EEC). The organization was created to begin removing barriers to the movement of goods, workers, capital, and services among its members. Also in 1957, the same six nations agreed to establish the European Atomic Energy Community (Euratom) to work together to develop nuclear energy for peaceful uses. The EEC and Euratom went into effect in 1958. The six member nations became known as the European Community, and both the Community and the EEC became known as the European Common Market. In 1967, the ECSC, the EEC, and Euratom merged their executive agencies to form a unified administrative system. The European Community admitted Britain, Denmark, and Ireland in 1973. Greece joined the organization in 1981, and Portugal and Spain joined in 1986. The Community was further enlarged in 1990 when West and East Germany merged as Germany, bringing the area of what was formerly East Germany into the organization.

Other organizations were formed in the 1950's and 1960's. The European Free Trade Association and the Organization for Economic Cooperation and Development were organized to aid economic activity.

Willy Brandt became chancellor of West Germany in 1969 and began to work to improve relations between eastern and western Europe. In 1970, government leaders of East and West Germany conferred for the first time since the division of Germany. That same year, West Germany signed nonaggression treaties with the Soviet Union and Poland.

In 1975, representatives from almost every European nation and from Canada, Cyprus, and the United States met in Helsinki, Finland, for the Conference on Security and Cooperation in Europe. The nations signed the first of the Helsinki Accords. In this agreement, the signers pledged to work for increased cooperation in matters of economics and peacekeeping and to promote human rights. In 1990, the leaders of the same nations held another conference in Paris. They signed an agreement that declared an end to the Cold War era of confrontation and division in Europe.

In 1987, the European Community completed ratification of the Single European Act. This act set the end of 1992 as a deadline for eliminating all customs controls and most other obstacles to the free movement of goods, services, workers, and capital among member nations. The act went into effect on Jan. 1, 1993.

In February 1992, representatives of the 12 member countries of the European Community signed the Treaty on European Union in Maastricht, the Netherlands. This pact, also known as the Maastricht Treaty, established the European Union when it went into effect in November 1993. The European Community was incorporated into the European Union (EU). The EU was formed to extend cooperation among the community's members to such areas as military policy, crime, and immigration.

The breakup of Communism. Beginning in the 1980's, fundamental changes occurred in the Soviet Union and eastern Europe. Mikhail S. Gorbachev, who became the leader of the Soviet Union in 1985, promoted two policies of reform—one of political and social reform, called *glasnost* (openness); and one of economic reform, called *perestroika.*

In the late 1980's, the reforms in the Soviet Union sparked reform movements across eastern Europe. Large numbers of people in Poland, Hungary, Czechoslovakia, East Germany, Romania, and Bulgaria staged demonstrations and demanded more freedom and an end to Communist rule. In 1989 and 1990, free multiparty elections were held in these countries and non-Communist parties gained control. The governments lifted restrictions on such civil liberties as freedom of speech, religion, and the press. They began to introduce free enterprise systems into their socialized economies.

In 1990, East and West Germany were unified into the single non-Communist nation of Germany. In 1991, the leaders of the Warsaw Pact nations formally dissolved the pact. Non-Communists gained control of Albania's government in 1992. In 1991 and early 1992, four of the six republics of Yugoslavia declared their independence and became non-Communist independent countries. They are Bosnia-Herzegovina, Croatia, Macedonia, and Slovenia. The two other Yugoslav republics—Serbia and Montenegro—formed a new, smaller Yugoslavia.

In 1991, Communist rule ended in the Soviet Union after conservative Communist officials failed in an attempt to overthrow Gorbachev. After this attempt, the Soviet parliament suspended all Communist Party activities. The parliament also recognized the independence of Estonia, Latvia, and Lithuania, which the Soviet Union had taken over in 1940. The 12 other Soviet republics took steps toward independence. On Dec. 25, 1991, Gorbachev resigned, and the Soviet Union was formally dissolved. The 12 republics became independent nations.

Recent developments. In the early 1990's, the area that made up the old Yugoslavia became a major European trouble spot. Ethnic Serbs in Croatia and Bosnia-Herzegovina fought the governments of those new countries for control of territory inhabited by Serbs. Peace agreements were signed in 1995. But Bosnia's ethnic groups remained divided, and hostilities continued.

In 1998, Serbian forces began attacks on the Serbian province of Kosovo, which was demanding independence. In March 1999, NATO began bombing military targets in Serbia to force the government to accept a peace agreement. In June, Serbia agreed to withdraw its forces, and NATO stopped the bombing. NATO sent an international peacekeeping force to Kosovo.

In 1999, many of the EU member nations began phasing in a common currency, called the *euro,* as part of a process called European Economic and Monetary Union (EMU). The euro replaced the traditional currencies of these countries, making trade easier among participating members.

Hugh D. Clout, M. Donald Hancock, and William M. Reddy

Related articles. *World Book* has articles on all the European countries and other political units, which are listed in the tables at the beginning of this article. Articles on many European cities are listed at the end of each country article. See also:

History

Aegean civilization
Age of Reason
Alexander the Great
Byzantine Empire
Charlemagne
Churchill, Sir Winston L. S.
Cold War
Communism
Counter Reformation
Crusades
Eastern Orthodox Churches (History)
Exploration (The great age of European exploration)
Feudalism
Franco-Prussian War
French Revolution
Greece, Ancient
Helsinki Accords
Hitler, Adolf
Holy Roman Empire
Humanism
Hundred Years' War
Industrial Revolution
Knights and knighthood
Manorialism
Marshall Plan
Marx, Karl
Middle Ages
Napoleon I
Reformation
Renaissance
Revolution of 1848
Rome, Ancient
Seven Years' War
Stalin, Joseph
Succession wars
Thirty Years' War
Versailles, Treaty of
Vienna, Congress of
Vikings
Warsaw Pact
World War I
World War II

Peoples

Angles
Basques
Celts
Cossacks
Franks
Goths
Gypsies
Jutes
Magyars
Sami
Saxons
Slavs
Vandals
Walloons

Organizations

Benelux
Common market
Euronext
Europe, Council of
European Free Trade Association
European Space Agency
European Economic and Monetary Union
European Union
North Atlantic Treaty Organization
Organization for Economic Cooperation and Development
Organization for Security and Cooperation in Europe
Western European Union

Physical features

See Island; Lake; Mountain; River; Waterfall and their lists of *Related articles.* See also the following articles:

Adriatic Sea
Aegean Sea
Alps
Arctic Ocean
Atlantic Ocean
Baltic Sea
Bay of Biscay
Black Sea
Bosporus
Caspian Sea
Danube River
Dardanelles

English Channel	Mount Elbrus	Volga River
Marmara, Sea of	North Sea	White Sea
Mediterranean Sea	Rhine River	

Regions

Balkans	Galicia	Macedonia (historical region)	Slavic countries
Baltic States	Iberia	Ruthenia	Transylvania
Bessarabia	Karelia	Scandinavia	Turkestan
Caucasus	Lapland	Siberia	Tuva
Crimea	Low Countries		

Other related articles

Bank (Europe)	Food	Political science (The development of political science)
Clothing (Clothing through the ages)	Furniture	Postal services (The history of postal services)
Democracy (The development of democracy)	Government	Prehistoric people
Economics	Language	Races, Human
Education (History)	Law (The development of law)	Science (The history of science)
Euro	Literacy (table)	Socialism
Flag (pictures: Flags of Europe; Historical flags of the world)	Mythology	Television (In Europe)
	Philosophy (The history of Western philosophy)	

Outline

I. People
- A. Population
- B. Ethnic groups

II. Ways of life
- A. City life
- B. Rural life
- C. The family
- D. Social class
- E. The role of government
- F. Languages
- G. Religions
- H. Education

III. The arts
- A. Ancient Greek and Roman art
- B. Medieval art
- C. Renaissance art
- D. Art since the Renaissance

IV. The land
- A. Land regions
- B. Physical features

V. Climate

VI. Plant and animal life
- A. Plants
- B. Animals

VII. Economy
- A. Industry
- B. Service industries
- C. Agriculture

VIII. History

Questions

Where did the earliest European civilizations develop?
What is the major religion of Europe?
How did a number of farms in Europe change after the collapse of Communism?
What was the Renaissance? The Reformation?
Why does most of Europe have a mild climate?
What is the *euro?*
When and where in Europe did modern industry begin?
What land region covers most of Europe?
What were the most important influences on European art during the Middle Ages?
What are some species of wildlife native only to Europe?

Additional resources

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Lands and Peoples, Vols. 3 and 4: Europe. Grolier, 2001. Younger readers.
Minahan, James. *One Europe, Many Nations.* Greenwood, 2000.
Urwin, Derek W. *A Political History of Western Europe Since 1945.* 5th ed. Longman Pub. Group, 1997.

Europe, Council of, is an organization of European nations that seeks to promote unity among its members in order to achieve economic and social progress. It has no real power and can only advise on economic, social, legal, cultural, scientific, and other matters.

The council consists of a joint committee, a secretariat-general, a committee of ministers with a representative from each member nation, and a parliamentary assembly with several members from each nation. The assembly makes recommendations to the ministers. The council's main areas of activity include culture and sport, education, human rights, and public health.

The council was formed in 1949. The founding members were Belgium, Denmark, France, Ireland, Italy, Luxembourg, the Netherlands, Norway, Sweden, and the United Kingdom. The organization's headquarters are in Strasbourg, France. M. Donald Hancock

European Community. See European Union.

European Economic and Monetary Union is the final step in the process of creating a single economic market among member nations of the European Union (EU). Through Economic and Monetary Union, also called EMU, EU members will finish combining their markets for goods, labor, and capital into one. This single market will save resources and make it easier for companies in different countries to do business with one another. A major task of EMU was to replace the many national currencies in the EU with one currency, called the *euro.* See **Euro.**

On Jan. 1, 1999, 11 members of the EU began to phase in the use of the euro. These countries were Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain. Four countries—Denmark, Greece, Sweden, and the United Kingdom—chose not to participate at first or did not qualify. Greece adopted the currency in 2001. The remaining three countries may adopt the euro in the future.

The EMU members began phasing in the euro by fixing the values of their traditional currencies to the value of the euro. Companies, banks, and stock exchanges in these nations also carried out many of their noncash transactions in euros. In early 2002, euro notes and coins replaced the national currencies. The European Central Bank regulates the euro. David L. Cleeton

European Free Trade Association (EFTA) is a trade group of four European nations. It works to remove tariffs and other trade obstacles in Western Europe and to uphold fair trade practices. Norway and Switzerland have been full members of EFTA since it began in 1960. Iceland joined in 1970. Liechtenstein became a full member in 1991.

Five founding members—Austria, Denmark, Portugal, Sweden, and the United Kingdom—have left EFTA. Denmark and the United Kingdom left in 1973, Portugal in 1986, and Austria and Sweden in 1995. Denmark, Portugal, and the United Kingdom left to join the European Community (EC), another economic association. The EC later became part of the European Union (EU). Austria and Sweden left EFTA to join the EU. Finland also left to join the EU in 1995. It had been an associate member of EFTA since 1961 and a full member since 1986.

EFTA achieved free trade in industrial goods among its members in 1966. Tariffs on industrial goods traded between EFTA and the EC were abolished by 1984.

In 1994, a treaty providing for a European Economic Area (EEA) went into effect. The EEA prohibited most trade barriers between the EU and two EFTA members—Norway and Iceland. In 1995, Liechtenstein joined the EEA. Much of EFTA members' trade is with the European Union. EFTA headquarters are in Geneva, Switzerland.

Critically reviewed by the European Free Trade Association

European Monetary System (EMS) is an arrangement between several European nations that aims to prevent wide swings in the prices of its members' currencies in relation to one another. Economists call the price of one nation's currency, expressed in terms of another's, an *exchange rate*. Exchange rates vary, depending on the supply of, and demand for, various currencies, as well as interest rates from country to country. What is now the European Union (EU) established the EMS in 1979 to stabilize exchange rates—and thus encourage trade and investment—among its members. The EU is a group of 15 Western European countries that promotes political and economic cooperation among its members.

Until 1999, the EMS linked the currencies of its members according to an arrangement called the Exchange Rate Mechanism (ERM), which used a method called the *target and band system*. Under this system, the ERM established target exchange rates for each currency. Each currency could vary only within a specific range, known as a *band*, above and below the target value. If a currency moved too far from its target price, the member nations had to intervene, by buying the currency or adjusting interest rates, until the rate returned to the specified band. The ERM was based on a specially created unit of value called the European Currency Unit (ECU). The currency of each nation had a target value in relation to the ECU and to other nations' currencies.

In 1999, a new currency unit, the *euro*, replaced the ECU. This event marked the final stage of a process known as Economic and Monetary Union (EMU). Eleven EU members froze their exchange rates by fixing them in terms of the euro. These nations were Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain. A 12th member, Greece, joined the group in 2001. In 2002, euro notes and coins replaced the currencies of the 12 nations.

David L. Cleeton

See also Euro; European Economic and Monetary Union; European Union; Exchange rate.

European Organization for Nuclear Research. See CERN.

European Space Agency (ESA) promotes the development of a cooperative space program among the nations of Western Europe. It was established in 1975 by merging the European Launch Development Association and the European Space and Research Organization (ESRO). ESRO had been formed in 1962. Members of the ESA are Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom.

The ESA combines parts of the space programs of its member countries. It has a council made up of representatives from each member nation, and a director-general who represents the interests of the agency itself. The council must approve all ESA programs.

The ESA continues the work of ESRO in developing spacecraft, satellites, and instruments and experiments for space exploration. From 1964 to 1972, ESRO produced and launched 7 satellites and 168 sounding rockets that collected data. The rockets explored regions in space too close to the earth for satellites to orbit.

In 1980, the ESA formed a private organization, Arianespace, which launches satellites from French Guiana on the rocket Ariane. The ESA also supervised the building of Spacelab, an orbiting laboratory. Spacelab went into orbit in 1983 aboard the United States space shuttle Columbia. Since then, many shuttle flights have carried Spacelab. In 1985, Arianespace launched the space probe Giotto. In 1986, Giotto passed within 370 miles (600 kilometers) of Halley's Comet, sending photographs and other information about the comet back to the earth. In 1990, the ESA and the United States launched the probe Ulysses from the U.S. space shuttle Discovery. The probe began making observations over the sun's south pole in mid-1994 and began making observations of the sun's north pole in mid-1995. William J. Cromie

See also Space exploration (Europe).

European Union, sometimes called the EU, is an organization of 15 Western European countries that promotes cooperation among its members. The members cooperate in many areas, including politics and economics. They have achieved the most success in creating a single economic market without internal barriers to trade and investment. The union's members are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom. The union's main offices are located in Brussels, Belgium.

The European Union has evolved from economic cooperation that began among Western European countries in the early 1950's. These countries eventually cooperated in economic affairs as members of the European Community (EC). In 1993, the EC members—which at that time included all the current EU members except Austria, Finland, and Sweden—extended their cooperation into the areas of Justice and Home Affairs and a Common Foreign and Security Policy. Justice and Home Affairs concerns cooperation in such areas as law enforcement and immigration. Through the Common Foreign and Security Policy, the nations deal with military and other foreign policy matters. The European Union was officially created when cooperation was extended to these two new areas. The three areas of cooperation are sometimes called the union's three "pillars."

The European Union is a major economic unit. Together, its members have more people than the United States. In addition, the total value of the goods and services produced by its members exceeds that of the goods and services produced by the United States. The combined value of the union's imports and exports is greater than that of any single country in the world. The United States is the union's main trading partner.

Working for cooperation

Internal affairs. The European Union works to improve the economies of its members by encouraging

WORLD BOOK map

The European Union consists of 15 nations in Western Europe who cooperate with one another economically and politically.

trade, investment, and economic competition. Union members impose no tariffs on one another and give *European citizenship* to their people. This means that citizens of member countries can live and work anywhere in the union. They may also vote in local and European Union elections in any member country in which they live, even if they are not citizens of that country.

The European Union also fosters economic development by adopting common policies and regulations in such areas as agriculture, transportation, health and safety, antitrust matters, and industrial standards. One such policy, the Common Agricultural Policy (CAP), controls the prices of farm goods, limits agricultural production, and gives *subsidies* (cash grants) to farmers. In addition, the union determines common policies for its members in such areas as immigration and the control of illegal drug trafficking and other international crimes.

The European Union administers programs in education and training and in science and technology. It also provides money for economic development in its poorer regions. This aid is aimed at achieving economic and social equality. The union's revenue comes from a general sales tax, levies on imports from nonmember countries, and contributions from members.

In 1999, most member states began to phase in a single currency, named the *euro,* as part of a process called European Economic and Monetary Union (EMU). A central bank, called the European Central Bank, conducts *monetary policy* for all EMU members. Officials use monetary policy to influence such economic factors as interest rates and the availability of money and loans.

The EMU includes 12 members of the European Union: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain. Companies, banks, and stock exchanges in these nations carry out many of their noncash transactions in euros. The value of the traditional currencies of each of the 12 countries was firmly tied to that of the euro. The euro began circulating as coins and paper money on Jan. 1, 2002. The traditional currencies of the 12 countries stopped circulating that same year.

Relations with other countries. The European Union is the main partner of the United States in efforts to negotiate and manage world trade rules. The union also cooperates with the United Nations (UN) and such agencies as the International Monetary Fund and the World Bank. The European Union belongs to the Food and Agriculture Organization, a UN agency. It also gives economic help to struggling nonmember nations.

The European Union sometimes helps resolve the military conflicts of nonmember countries. A defense alliance among several EU nations called the Western European Union performed these duties for many years. The European Union gradually took over these responsibilities in the early 2000's. The EU also works closely with the North Atlantic Treaty Organization (NATO). NATO is a larger defense alliance among whose members are the United States, Canada, and numerous European countries, including most members of the EU.

Governing institutions

The European Union has five major institutions that share its executive, legislative, and judicial functions. These institutions are the European Council, the Council of Ministers, the European Commission, the European Parliament, and the European Court of Justice.

The European Council is the union's supreme political body. It establishes the goals of the union. The council consists of the heads of state or government of each member nation. The chairperson of the council is the leader of the country that holds the presidency of the union. Each member nation serves as president of the union for six months in rotation. The council meets at least twice a year. Each meeting is held in the capital of the country that holds the presidency, or in Brussels.

The Council of Ministers approves legislation for the European Union. It cannot propose legislation, but it can accept or reject legislative proposals from the European Commission and request proposals from the commission. The Council of Ministers also coordinates the economic policies of the union's members. The council makes many of its most important decisions by unanimous agreement. The council consists of people who serve as cabinet ministers in the government of their home nation. The council usually meets in Brussels, but it also can conduct meetings in the capital of the country that holds the union's presidency.

The European Commission proposes legislation to the Council of Ministers. It also safeguards the treaties on which the union is based and oversees implementation of the union's decisions. The commission consists of 20 commissioners, including a president, all of whom are chosen by common consent of the national governments and approved by the European Parliament. The commissioners serve five-year terms.

The commission president is the principal leader of the European Union. With the help of the other commissioners, the president directs the development of new legislation, oversees the implementation of union decisions, and manages the budget. All the commissioners pledge to put the union's welfare above that of their home countries. The commission meets in Brussels.

The European Parliament, despite its name, cannot pass laws. But it does debate proposals of the European Commission and advises the commission and the Council of Ministers. The commission and the council must consider the parliament's views. The parliament's powers are strongest in budget matters. It can sometimes veto a budget proposal of the European Commission. The parliament can also expel the entire commission by a two-thirds vote. The parliament has more than 600 members, each serving a five-year term. Voters in each member country elect a certain percentage of the parliament's members. The smaller countries have greater representation per person than the larger countries do. The parliament meets in Strasbourg, France.

The European Court of Justice is the supreme court of the European Union. It decides whether actions of other EU bodies, member governments, and private organizations comply with the rules of the union. The court hears appeals on matters brought by member countries, the commission, the Council of Ministers, or private citizens. The court's decisions are final and binding on all parties, including the member governments. Its 13 judges are chosen by unanimous agreement of the member countries. The judges serve six-year terms. The European Court of Justice sits in Luxembourg.

History

Beginnings. After World War II ended in 1945, Jean Monnet, a French statesman, promoted the idea of gradually uniting the democratic European nations both economically and politically (see **Monnet, Jean**). As a result, in 1951, Belgium, France, Italy, Luxembourg, the Netherlands, and West Germany signed the Treaty of Paris, which established the European Coal and Steel Community (ECSC). The ECSC united its six member nations in a single common market for the production and trade of coal, steel, iron ore, and scrap metal. It abolished all trade barriers among the members for these products. It allowed coal and steel workers from any member nation to work anywhere in the ECSC countries. The ECSC began operating in 1952.

Formation of the European Community. The success of the ECSC led its six members to sign the Treaties of Rome in 1957. These agreements broadened the countries' cooperation by establishing the European Atomic Energy Community (Euratom) and the European Economic Community (EEC). Through Euratom, the nations pooled resources to develop nuclear energy for electric power production and other peaceful uses. The EEC worked to combine the members' economic resources. Euratom and the EEC began operating in 1958. They shared the ECSC's judicial and legislative bodies but had separate executive agencies. In 1967, the three organizations merged their executive agencies. The ECSC, Euratom, and the EEC together became known as the European Community (EC).

Increasing cooperation. By mid-1968, the EC members had eliminated all tariffs affecting trade among themselves and established a common tariff on goods from other countries. As a result, the volume of trade among member countries rose quickly. The elimination of tariffs on trade within the EC allowed member countries to increase their economic efficiency and substantially raise their citizens' standard of living.

In the early 1970's, the EC began managing the exchange rates of the currencies of some of its members, notably West Germany and France. EC efforts to stabilize exchange rates were strengthened in 1979 when its members formed the European Monetary System (EMS). The EMS required that the value of member countries' currencies not move above or below set limits in relation to each other (see **European Monetary System**).

Over the years, the European Community admitted six new members. Denmark, Ireland, and the United Kingdom were admitted in 1973. Greece joined the EC in 1981, and Portugal and Spain became members in 1986.

Beginning in 1989, many Communist countries in Eastern Europe moved away from Communist rule. They held democratic elections and reduced government control of their economies. The EC then established special agreements with these countries on trade, economic aid, and political relations. In 1990, West Germany and East Germany united. The new, united Germany replaced West Germany as an EC member.

In 1987, the EC completed ratification of the Single European Act. This act called for ending customs controls and other obstacles to the movement of goods, services, workers, and capital among EC members. It took effect on Jan. 1, 1993. But parts of the act have not yet been implemented. For example, passport checks are still required for travel between some member countries.

Formation of the European Union. In 1992, representatives of the 12 EC members signed the Treaty on European Union in Maastricht, the Netherlands. This pact, also called the Maastricht Treaty, took effect in November 1993. It provided for creation of the European Union. It also called for founding the European Central Bank and adopting a single currency, later named the euro. The central bank began operations in 1998, and 11 EU countries—Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain—began to use the euro in 1999. In 1995, Austria, Finland, and Sweden became full EU members.

In 2001, Greece began to phase in the euro. In 2002, euro notes and coins went into circulation and replaced the traditional currencies of Greece and the 11 other EU countries that adopted the euro. C. Randall Henning

See also **Euro; European Economic and Monetary Union.**

Additional resources

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Europium, *yu ROH pee uhm* (chemical symbol, Eu), is one of the rare-earth metals. Its atomic number is 63, and its atomic weight is 151.964. Its density is 5.245 grams per cubic centimeter at 25 °C (see **Density**). The French scientist Eugène Demarçay first discovered the element in 1901. He named it *europium* in honor of Europe. Europium occurs in cerium minerals. The soft, silver metal is prepared by vacuum distillation of a mixture of europium oxide and lanthanum metal or misch metal. It melts at 822 °C and boils at 1529 °C. A substance that contains europium provides the red color in color television screens. See also **Element, Chemical** (table); **Rare earth.** Larry C. Thompson

Eurydice, *yoo RIHD ih see,* in Greek mythology, was a tree nymph loved by Orpheus, who was a legendary Greek musician. On their wedding day, Eurydice accidentally stepped on a snake and died from its bite. Another version of her death tells that she tripped over the snake as she fled from the amorous advances of Aristaeus, a rural divinity. After her death, Eurydice descended into the underworld, which was ruled by the god Hades and his wife, Persephone. Orpheus was determined to rescue Eurydice. He went to the underworld and charmed the ghosts of the dead with his music.

Hades and Persephone agreed to release Eurydice only if Orpheus would walk ahead and not look back at her until they both reached the upper world. As they approached the light, Orpheus turned around to look at Eurydice because he did not hear her footsteps. Eurydice was immediately drawn back to the underworld forever. Luci Berkowitz

Euthanasia, *yoo thuh NAY zhuh,* is the practice of painlessly ending the lives of people who have incurable, painful, or distressing diseases or handicaps. It may occur when incurably ill people ask their physician—or a friend or relative—to put them to death or to allow them to die. It may also occur when ill people ask others to help them commit suicide. Euthanasia is sometimes called mercy killing.

Euthanasia is controversial. Some people believe patients should have an unqualified right to die. Others consider all forms of euthanasia to be murder or suicide and thus immoral. Still others approve of some forms of euthanasia and disapprove of others. Very few countries have laws specifically allowing euthanasia. Some countries tolerate mercy killing without actually legalizing it.

Active and passive euthanasia. Many people oppose *active euthanasia,* such as the injection of a lethal drug, because it requires one person to deliberately kill another. Fewer people oppose *passive euthanasia*—the withdrawal of life-sustaining medical treatment—for patients who request it. Belgium and the Netherlands are the only two countries that have legalized active euthanasia under certain conditions.

In 1990, the Supreme Court of the United States ruled that patients have a right to passive euthanasia if they have clearly made their wishes known. People can express their wishes in documents called *living wills* and by granting *durable powers of attorney.* In living wills, people state what kind of care they would prefer if, due to injury or disease, they could not express their wishes. In the granting of durable powers of attorney, individuals name one or more persons whom they wish to make decisions about their medical care if they should lose the ability to communicate such decisions themselves.

Self-induced euthanasia occurs when people end their own lives painlessly. In some cases, physicians provide lethal drugs that patients then take to kill themselves. This type of euthanasia is called *physician-assisted suicide.* Few countries have had laws permitting it. In the United States in the 1990's, Jack Kevorkian, a Michigan doctor, focused national attention on physician-assisted suicide by helping gravely ill people kill themselves. In 1999, a Michigan jury convicted him of murder in a case in which he performed active euthanasia. Many states have laws against physician-assisted suicide. But a law that specifically permits it took effect in Oregon in 1997. Oregon is the only state with such a law.

Many people support the concept of physician-assisted suicide. Many of those who oppose the practice argue that doctors should not help people kill themselves, because their job is to preserve life. David C. Thomasma

See also **Death** (The right to die); **Living will; Medical ethics; Suicide.**

Additional resources

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Roberts, Carolyn S., and Gorman, Martha. *Euthanasia: A Reference Handbook.* ABC-Clio, 1996.

Eutrophication, *yoo truh fuh KAY shuhn,* is a process that affects lakes and other bodies of water. During eutrophication, the quality of the affected water deteriorates until it becomes unfit for use by human beings. Lakes and rivers become foul smelling and can no longer support many fish and other animals.

Some lakes naturally become eutrophic over hundreds of thousands of years. But during the 1900's, many lakes and rivers became eutrophic because people polluted them. Such accelerated eutrophication caused by human activities is called *cultural eutrophication.*

How eutrophication occurs. Water bodies support a natural cycle of life. The bacteria of decay break down the wastes of fish and other organisms, releasing such *nutrients* (nourishing substances) as carbon dioxide, nitrate, and phosphate. Simple plantlike organisms called *algae* feed on the nutrients. Microscopic animals called *zooplankton* eat the algae, and fish eat the zooplankton. When this cycle is in balance, each member of the cycle supports the others. Fish get food and oxygen from algae. Bacteria use organic matter from fish and oxygen from algae, and algae feed on the products of decay.

People upset the balance when they pollute the water with wastes, which provide many nutrients. Algae consume the excess nutrients. They become so well nourished that they grow faster than fish can eat them. Thick layers of algae, called *algal blooms,* spread over the water. The lower layers of algal blooms cannot get the light they need for photosynthesis. These algae soon die and decay, using up huge quantities of oxygen in the water.

Fish and other water animals die when the oxygen supply in the water becomes too small to sustain them. As the bodies of the animals decay, they consume still more oxygen. Without oxygen, the bacteria of decay can no longer function, and foul-smelling wastes accumulate. The dead fish and plants and other wastes sink to the bottom of the water and form a layer of soft mud. As the mud becomes thicker, the lake gradually shrinks. Some lakes eventually fill and become swamps.

Eutrophication and water pollution. Eutrophication is a major pollution problem. Many of the excess nutrients that enter bodies of water and cause the problem come from sewage treatment plants. In particular, the use of detergents that contain phosphate greatly increases the quantity of phosphate entering rivers and lakes through sewage. Rain also washes the nitrate from fertilizers used on farmland, gardens, and lawns into ponds and streams. Nitrates from automobile exhaust enter the water in rain and snow, and industrial plants discharge nutrients in wastewater. Melody J. Hunt

See also **Environmental pollution** (Water pollution); **Water pollution** (Effects; diagram).

Evangelical Lutheran Church in America is the largest Lutheran denomination in the United States. The body was formed by the merger of the Lutheran Church in America, the American Lutheran Church, and the Association of Evangelical Lutheran Churches. The denomination officially came into being in 1988.

The church is organized into 65 regional jurisdictional units called *synods,* each headed by a bishop. The leader of the denomination is a bishop elected for a four-year term. The church ordains women, maintains ecumenical ties with other churches, supports an extensive international and domestic mission program, and seeks increased participation from minorities.

The Evangelical Lutheran Church in America traces its roots back to Lutheran immigrants who came from Germany and Scandinavian countries in colonial times and during the 1800's. The headquarters of the church are in Chicago. Critically reviewed by the Evangelical Lutheran Church in America

See also Lutherans.

Evangelicalism is a term used primarily to describe the religious views of various theologically conservative Protestants in Europe and North America. The term *evangelical* means *of the Gospel.* It comes from a Greek word for *gospel,* which means *good news.*

Martin Luther and other leaders of the Protestant Reformation used the term *evangelical* in the 1500's. They used it in promoting a message that stressed salvation through faith in Jesus Christ, the authority of the Bible, and the equality of all believers before God. Many Lutheran churches today include some form of the word *evangelical* in their names.

In the 1700's, evangelicalism came to describe religious revivals such as those led by the English preachers John Wesley and George Whitefield. These religious leaders emphasized the need for a personal conversion experience through a special act of God's grace. They also stressed the importance of leading a holy and disciplined life.

During the 1800's, evangelical denominations were the most visible and influential religious groups in the United States. The "Evangelical United Front" was formed by Baptists, Congregationalists, the Dutch Reformed, Methodists, Presbyterians, and many smaller groups. These bodies promoted revivals and organized such reform movements as *temperance* (nonuse of alcohol) and abolition.

By the end of the 1800's, a division between more liberal and more conservative Protestants, as well as the growth of non-Protestant religions, ended the dominance of evangelicalism in American religious culture. After World War II (1939-1945), a "new evangelical" movement emerged, closely linked with the popular preacher Billy Graham. Mark A. Noll

See also Methodists; Revivalism; Wesley, John; Whitefield, George; Graham, Billy.

Evangeline. See Longfellow, Henry Wadsworth.

Evans, Sir Arthur John (1851-1941), a British archaeologist, became known for excavations he started on the island of Crete in 1893. He found clay tablets bearing an early form of Greek writing. This form preceded the writing of the Phoenicians. He also uncovered the Palace of Minos at Knossos, on which most knowledge of pre-Greek Minoan civilization is based.

Evans was born on July 8, 1851, in Hertfordshire, England. He graduated from Oxford and Göttingen (Germany) universities. He was curator of the Ashmolean Museum at Oxford. Evans wrote the book *Palace of Minos* (1922-1935). He was knighted in 1911. David B. Stout

See also Knossos.

Evans, Mary Ann. See Eliot, George.

Evans, Oliver (1755-1819), an American engineer, inventor, and manufacturer, built what was probably America's first self-propelled land vehicle (see Automobile [The steam car]). The vehicle, a steam-powered dredge to be used in the Philadelphia harbor, was completed in 1805. In 1802, Evans had built one of the first high-pressure steam engines. These engines became highly successful, and Evans manufactured large numbers of them for use in flour mills, locomotives, and steamboats. Evans designed a steam-propelled carriage, but it was never built. Evans was born on Sept. 13, 1755, near Newport, Delaware. Joel Webb Eastman

Evans, Walker (1903-1975), was an American photographer who became best known for his pictures of Southern sharecroppers of the 1930's. Evans's photographs capture the poverty and desolation of rural life in the Southern United States during the Great Depression. A group of 31 of his pictures and a text by James Agee were published in *Let Us Now Praise Famous Men* (1941). The book portrays the lives of three poor sharecropper families in Alabama.

Evans was born on Nov. 2, 1903, in St. Louis, Missouri. He took up photography in 1928 after failing in an attempt to be a writer. Evans often photographed such common subjects as billboards, pedestrians, and subway riders. During the 1930's, he took pictures of farms, towns, and cities in the East and the South for the government. Many of these pictures appear in his book *American Photographs* (1938).

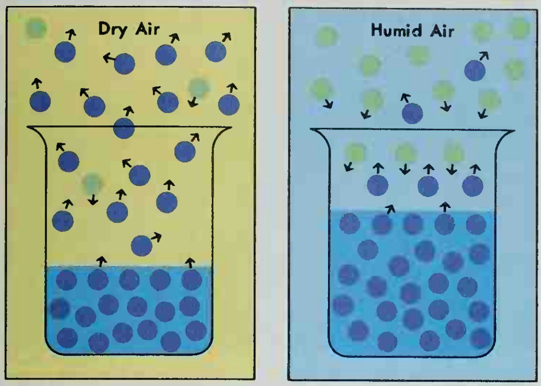
From 1945 to 1965, Evans worked for *Fortune* magazine. He taught at Yale University from 1965 until his death. John G. Freeman

Evaporation is the conversion of a liquid or solid to a gas. Energy in the form of heat causes evaporation. For example, evaporation occurs when water in an open pan in a warm room disappears, leaving a dry pan. Sometimes solids may change directly into *vapor* (a gaseous form) without first becoming a liquid. This process is called *sublimation.* The vaporization of dry ice (solid carbon dioxide) is an example of sublimation.

How evaporation occurs. The molecules of all substances have a certain amount of *kinetic energy* (energy of motion). This energy is provided by heat from the surroundings, including other nearby molecules. The more energy molecules have, the faster they move, making it possible for them to break the bonds that hold them together. Evaporation occurs when the molecules of a substance have enough kinetic energy to escape from the substance's surface as vapor. The escaping molecules absorb heat energy from the remaining molecules and cause the substance to become cooler.

Evaporation occurs more rapidly when temperature is increased. An increase in temperature increases the energy of a substance's molecules, enabling them to escape at a faster rate. Different substances vary greatly in the speed at which they evaporate at a given temperature. For example, alcohol, ammonia, and the anesthetic

How evaporation occurs



WORLD BOOK diagrams

In dry air, water evaporates readily. Many molecules escape from the container as vapor, but few enter to become liquid. Dry air contains so little moisture that condensation hardly occurs.

In humid air, water evaporates slowly, if at all. The vaporization occurring at the surface of the water in the container is quickly matched by the condensation of moisture in the humid air.

diethyl ether evaporate quickly when poured onto an open surface at room temperature. Such substances are said to be *volatile.* Other substances, such as table salt (sodium chloride), evaporate extremely slowly, if at all, at room temperature. They are said to be *nonvolatile.*

A substance that is nonvolatile at one temperature may become volatile if it is heated. In this sense, the boiling point of a substance is a measure of its volatility. The lower the boiling point of a substance, the more easily it evaporates. See **Boiling point**.

The *vapor pressure* of a substance also helps determine how readily the substance evaporates. Vapor pressure is the pressure produced by vapor molecules escaping from the surface of a liquid or solid. The greater a substance's vapor pressure, the faster the substance evaporates. As a substance gains heat, more and more molecules escape. Vapor pressure increases until the number of molecules escaping from the liquid or solid equals the number returning to it. When these numbers are equal, the amount of the liquid or solid does not change. For example, water evaporates slowly, if at all, when exposed to humid air because the vaporization occurring at the surface of the water is almost matched by the condensation of moisture in the air. But water evaporates rapidly in dry air because dry air has only a fraction of the maximum vapor pressure of water.

Uses of evaporation. Evaporation plays an important part in the earth's water cycle. Water evaporated from the earth by the heat of the sun later falls as precipitation. Because evaporating molecules absorb heat from their surroundings, evaporation functions as a cooling process. Air-conditioning and refrigeration systems contain evaporators that remove heat and moisture from the surrounding air and so reduce the temperature. The evaporation of perspiration cools the skin.

Evaporation provides a way to separate mixtures. In distillation, mixtures of liquids that differ in *volatility* (ease of evaporation) are heated to form a vapor that is then condensed. The resulting liquid contains a greater proportion of the more volatile substance than does the original mixture. Such products as alcoholic beverages and gasoline are manufactured by distillation.

Evaporation also serves as a means of concentrating nonvolatile substances. For example, the juice from sugar cane is heated until nearly all the liquid evaporates. This process produces a concentrated sugar solution from which sugar crystals form. Marye Anne Fox

See also **Cloud; Steam; Sublimation; Vapor.**

Evarts, William Maxwell (1818-1901), an American lawyer, gained fame for successfully handling important trials. He helped President Andrew Johnson gain acquittal in his impeachment trial in 1868 (see **Johnson, Andrew** [Impeachment]). Evarts served as attorney general of the United States in 1868 and 1869, as U.S. secretary of state from 1877 to 1881, and as U.S. senator from New York from 1885 to 1893. As president of the New York City Bar Association, he led movements for law reform and helped smash the "Tweed Ring" (see **Tweed, William M.**). His closing argument for the defense in a case against Henry Ward Beecher lasted eight days. Evarts was born in Boston. Daniel J. Dykstra

Eve. See **Adam and Eve.**

Evening primrose is any of several related wild flowering plants that grow from Labrador to Florida and westward to Wyoming and New Mexico. The plants may be 1 to 8 feet (30 to 240 centimeters) high, and often have shrubby bases. The hairy leaves grow 2 to 6 inches (5 to 15 centimeters) long. Saucer-shaped flowers grow among the upper leaves. They may be white, bright yellow, or rosy-pink. The blossoms may be 1 to 4 inches (3 to 10 centimeters) wide. One species, called the *small-flowered evening primrose,* has flowers that grow no more than one-half inch (13 millimeters) wide.

Scientific classification. Evening primroses are in the family Onagraceae. The scientific name for the common evening primrose is *Oenothera biennis.* The small-flowered plant is *O. cruciata.* Melinda F. Denton

Evening star is any planet that can be seen after sunset. The planets Venus and Mercury are most often seen as evening stars. Because these two planets move in orbits closer to the sun than the earth's orbit, they appear to move from one side of the sun to the other. The two planets can be seen only in the western sky after sunset or in the eastern sky before sunrise. When either of the planets is seen at sunrise, it is called a *morning star.*

Planets are not really stars, but solid bodies in our own solar system. They do not give off their own light as stars do. They shine by reflecting sunlight. Ancient people thought planets were wandering stars. By Roman times, they recognized that the morning stars and evening stars were the same. But it was not until 1543 that the Polish astronomer Nicolaus Copernicus identified their positions in the solar system. C. R. O'Dell

Everest, Mount. See **Mount Everest.**

Everett, Edward (1794-1865), an American statesman, was considered one of the greatest orators of his day. He was the chief speaker in Gettysburg, Pennsylvania, on Nov. 19, 1863, the day that Abraham Lincoln delivered his famous Gettysburg Address (see **Lincoln, Abraham** [The Gettysburg Address]). Everett was impressed by Lincoln's logic and ability to say so much in so few words. He declared Lincoln's speech would live for generations.

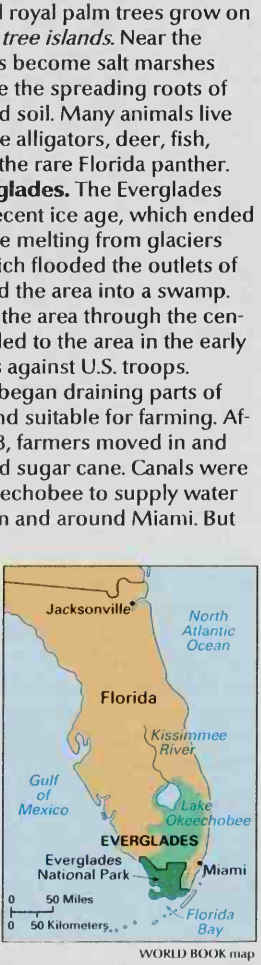
Everett was born in Dorchester, Massachusetts. At 19, he became a Unitarian minister, but he resigned from his first pastorate in less than two years. He studied in Germany and England and returned to become professor of Greek literature at Harvard College. For four years, he edited the *North American Review.* Then he served five terms in Congress. He was governor of Massachusetts from 1836 to 1840, U.S. minister to the United Kingdom from 1841 to 1845, and president of Harvard from 1846 to 1849. In 1852, he became secretary of state in President Millard Fillmore's Cabinet. Soon after, Everett was elected U.S. senator from Massachusetts. He resigned from his Senate post in 1854. In 1860, he was the Constitutional Union Party's candidate for vice president (see **Constitutional Union Party**). James M. McPherson

Everglades, in southern Florida, are one of the most interesting and unusual swamp areas in the world. Everglades National Park, which makes up about one-fifth of the Everglades' original area, covers 1,506,499 acres (609,658 hectares). The Everglades extend from Lake Okeechobee to Florida Bay and the Gulf of Mexico.

The northern part of the Everglades consists of a prairie covered by shallow water and by saw grass, a grasslike plant with sharp, jagged edges that grows as high as 12 feet (3.7 meters) in some places. Bustic, gumbo limbo, live oak, mastic, and royal palm trees grow on mounds of higher land called *tree islands.* Near the southern coast, the Everglades become salt marshes and mangrove swamps, where the spreading roots of mangrove trees catch and hold soil. Many animals live in the Everglades. They include alligators, deer, fish, herons, pelicans, snakes, and the rare Florida panther.

Development of the Everglades. The Everglades were created after the most recent ice age, which ended about 11,500 years ago. The ice melting from glaciers raised the level of the sea, which flooded the outlets of Everglades streams and turned the area into a swamp. Various peoples have lived in the area through the centuries. The Seminole Indians fled to the area in the early 1800's during a period of wars against U.S. troops.

In 1906, the state of Florida began draining parts of the Everglades to make the land suitable for farming. After World War I ended in 1918, farmers moved in and began growing vegetables and sugar cane. Canals were built southeast from Lake Okeechobee to supply water to the growing communities in and around Miami. But by the 1940's, the U.S. government had decided to try to preserve a section of the Everglades. Thus, the southwestern region became the Everglades National Park in 1947.



WORLD BOOK map

Location of the Everglades

Environmental problems. In spite of the efforts to protect the Everglades, conditions within the wetlands worsened. The Kissimmee River is the main source of fresh water for Lake Okeechobee and the southern wetlands. In the 1960's, the U.S. Army Corps of Engineers forced the waters of the winding Kissimmee into a straight, concrete canal. These measures sharply reduced the flow of water into the Everglades, with disastrous results for plants and wildlife.

© Lynn M. Stone

The northern part of the Everglades consists of a prairie covered by shallow water and saw grass. A heron wades in the water and searches for fish to eat.

The massive development of southern Florida in the late 1900's also damaged the Everglades' water supply. Cities surrounding the Everglades use huge amounts of the water supply. The growth of agriculture in an area just south of Lake Okeechobee has also contributed to the water problem. Sugar plantations and vegetable farms consume much water, and harmful chemicals used in agriculture run off into the water supply.

Plant species that are not native to the Everglades also pose problems for the area. Seeds from plants, including paperbark trees and Brazilian pepper trees, have been dispersed to the Everglades by high winds. When such seeds take root and develop into plants, they can overpower and replace native Everglades species.

Saving the Everglades. Many groups have joined the fight to save the Everglades. The state of Florida has bought land around Lake Okeechobee to create new marshes that will store water and filter out toxic chemicals before releasing the additional water into the wetlands to the south. The U.S. Army Corps of Engineers is working on restoring the Kissimmee to its original course. In 1999, the Corps also introduced a 20-year plan to reconnect the various parts of the Everglades that have been fragmented by the building of artificial barriers and drainage canals. Peter O. Muller

See also **Everglades National Park; Lake Okeechobee.**

Everglades National Park is one of the few subtropical regions in the United States. Located on the southwestern tip of the Florida peninsula, the park includes Ten Thousand Islands along the Gulf of Mexico and parts of the Everglades and the Big Cypress Swamp. Its junglelike plant life includes saw grass, delicate orchids, lacy cypress trees, pines, palms, and mangrove trees that form a thick tangle as high as 70 feet (21 meters). Crocodiles, alligators, manatees, huge turtles, and many swamp birds live there. The park was established in 1947. For its area, see **National Park System** (table: National parks).

Critically reviewed by the National Park Service

Evergreen is a plant that remains green throughout the year. It grows new leaves before shedding the old ones. Many evergreens keep their leaves for several years. The leaves of some of them are tougher and more leathery than those of other plants. Some evergreens, such as the cone-bearing trees, have needle-shaped leaves. These leaves have less surface area than broad, flat leaves and can resist changes in temperature more easily. Many tropical plants are called broadleaf evergreens to distinguish them from needle-leaved ones. Both kinds of leaves contain *chlorophyll,* the green coloring matter used by plants to make food.

The best-known North American evergreen trees include pine, fir, spruce, hemlock, cedar, cypress, and yew. Holly, box, ivy, and myrtle are other common evergreens. Rhododendron, laurel, some magnolias, and most tropical plants are evergreens. Pines and spruces are valuable timber trees. Ross W. Wein

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Conifer	Ivy	Rhododendron	Tree (Kinds)
Cycad	Juniper		Wax myrtle
Cypress	Laurel		Yew
	Magnolia		

Evers, Medgar (1925-1963), was an African American civil rights leader. He fought against segregation and racial discrimination in Mississippi during the 1950's and early 1960's. Evers was shot and killed outside his home in Jackson, Mississippi, on June 12, 1963.

Medgar Wiley Evers was born in Decatur, Mississippi. He enlisted in the U.S. Army in 1942 during World War II. Evers received a bachelor's degree from Alcorn Agricultural and Mechanical College (now Alcorn State University) in 1952. From 1954 to 1963, he served on the staff of the National Association for the Advancement of Colored People (NAACP) as field secretary for Mississippi. Evers traveled throughout the state, encouraging African Americans to register to vote. He also organized African American *boycotts* (buyers' strikes) against white-owned firms that practiced racial discrimination.

Evers soon became Mississippi's best-known champion of civil rights and a target of white supremacists, who violently opposed programs designed to guarantee blacks' rights. Ten days after Evers's murder, police arrested white supremacist Byron De La Beckwith for the crime. Beckwith, whose fingerprints were on the rifle that killed Evers, was tried twice in 1964 for the slaying. But each time, an all-white jury could not reach a verdict. The charges against Beckwith were dropped in 1969. In 1989, the case was reopened after new evidence was found. In 1994, a jury of eight African Americans and four whites convicted Beckwith of Evers's murder.

Medgar's brother Charles succeeded him as field secretary. In 1969, Charles was elected mayor of Fayette, Mississippi. He held that office until 1981 and again from 1985 to 1989. Medgar's widow, Myrlie Evers-Williams, served as chairwoman of the NAACP's board of directors from 1995 to 1998. In 1998, she set up the Medgar Evers Institute to work for civil rights. David J. Garrow

Evers-Williams, Myrlie (1933-), served as chairwoman of the board of the National Association for the Advancement of Colored People (NAACP) from 1995 to 1998. She won election to the position by defeating William F. Gibson, who had been board chairman since 1985. The election followed months of public disagreement over the NAACP's financial and personnel practices under both Gibson and executive director Benjamin Chavis, who was dismissed in 1994. Evers-Williams did not seek reelection in 1998.

Evers-Williams was born Myrlie Louise Beasley in Vicksburg, Mississippi. In 1951, she married Medgar Evers, who later became the NAACP's Mississippi field secretary. In 1963, Evers was assassinated. More than 30 years later, in 1994, Evers-Williams played a key role in winning the conviction of white supremacist Byron De La Beckwith for the murder. After her husband's assassination, Mrs. Evers moved to California, where she graduated from Pomona College in 1968. She then held a series of positions as a business executive. From 1987 to 1990, she was commissioner of the Los Angeles Board of Public Works. In 1976, she married Walter Williams, a dockworker and civil rights worker. In 1998, Evers-Williams set up the Medgar Evers Institute to promote civil rights. David J. Garrow

Evert, Chris (1954-), was an American tennis champion of the 1970's and 1980's and one of the top women players in the history of tennis. She was noted for her powerful two-handed backhand stroke and the depth and accuracy of her shots.

Christine Marie Evert was born in Fort Lauderdale, Florida. She became a professional tennis player in 1972. In 1974, Evert won the women's singles title in the All-England (Wimbledon) Championships and the French Open. Evert also won the United States Open six times from 1975 to 1982; the French Open six more times from 1975 to 1986; Wimbledon twice more; and the Australian Open twice. In 1989, Evert announced her retirement from tournament competition. J. Norman Arey

Eviction, in law, is an action that deprives a tenant of the use of leased premises, such as an apartment or an office. An eviction can occur if either the tenant or the landlord violates the lease. A landlord may evict a tenant who owes rent or has substantially failed in some other way to meet the lease obligations. Such obligations include not disturbing other tenants. On the other hand, the landlord may have made the premises unfit for the tenant's use. For example, the landlord may have refused to make repairs that were necessary for the tenant's comfort and safety. In such cases, the tenant no longer must pay rent if he or she abandons the premises within a reasonable time. James E. Krier

Evidence is information that tends to prove or disprove a fact in question. Evidence may consist of documents, public records, or the testimony of witnesses. It may be an object, such as a murder weapon or a signed contract, the existence or appearance of which provides information about the fact in question. Most evidence is presented through witnesses whom a judge declares *competent* (mentally able) to testify. Insane people and some children may be declared incompetent.

Each party to a legal dispute presents evidence to the court. The *trier of fact* considers the evidence and decides the disputed facts. In a jury trial, the trier of fact is the jury. In a nonjury trial, it is the judge.

Evidence is used in other fields besides law. For example, scientists gather evidence to support theories.

This article chiefly discusses court evidence.

Burden of proof is the obligation to provide evidence, and it falls on one of the parties to a lawsuit. In a criminal case, the prosecuting attorney has the burden of proving the defendant's guilt "beyond a reasonable doubt." In civil trials, the party that is suing, called the *plaintiff,* need only prove a fact by a *fair preponderance* (greater weight) of the evidence.

The burden of proof may shift during a trial. For example, a plaintiff suing a defendant for injuries suffered in an automobile accident must prove that the defendant was negligent. But the burden of proof shifts to the defendant if the defendant claims that the plaintiff's actions contributed to the accident.

Kinds of evidence. There are two general kinds of evidence—*direct evidence* and *circumstantial evidence.* Direct evidence tends to prove a fact without the help of other evidence. For example, an eyewitness to a murder gives direct evidence by testifying that he or she saw the defendant kill the victim. Circumstantial evidence tends to prove facts that support the main fact in question, but such evidence does not tend directly to prove the main fact itself. Witnesses may give circumstantial evidence by testifying that they saw the defendant leave the murder scene. This evidence indicates that the defendant could have killed the victim, but does not prove it.

Rules regulate the admission of evidence in court. The judge decides whether evidence is admissible under the rules. In 1975, United States federal courts began to operate under uniform rules. But state courts follow rules of evidence that may vary from state to state.

One type of evidence that generally is not admitted is *hearsay.* Such evidence is testimony in which a witness tells the court what he or she heard others say, rather than what the witness knows from firsthand experience.

Relevancy. Evidence must be *relevant* to be admitted in court—that is, it must relate to and help resolve a significant question in a case. Evidence that seems relevant may be excluded because it might prejudice or mislead a jury. For example, evidence that a defendant has previously committed crimes is not ordinarily admitted.

Privilege is the right to withhold evidence to protect an important interest or relationship. The U.S. Constitution provides some privileges. For example, accused people cannot be forced to give evidence against themselves at a criminal trial. Other privileges include the right not to reveal confidential communication between husbands and wives, attorneys and clients, or priests and the people whose confessions they hear.

Presumptions. If evidence about a fact is lacking, a rule of law may state that the fact is proved by other facts. Such a statement is called a *presumption.* For example, proof that a person has been missing for at least seven years may result in the presumption that he or she is dead. Jack M. Kress

See also **Crime laboratory; DNA fingerprinting; Trial; Witness.**

Evil eye is the supposed power to harm people or their possessions by merely looking at them. According to superstition, an evil person who has this power may use it to cause such misfortune as death, illness, or property damage. A person may also unknowingly have the evil eye and cause harm unintentionally. To avoid the evil eye, many people utter such phrases as "God bless you" or wear blue beads or other protective charms. For thousands of years, people in many parts of the world have believed in the evil eye. Today, the belief is fairly common in India and in the countries bordering the Mediterranean Sea. See also **Amulet.** Alan Dundes

Evolution is a process of change over time. The word *evolution* may refer to various types of change. For example, scientists generally describe the formation of the universe as having occurred through evolution. Many astronomers think that the stars and planets evolved from a huge cloud of hot gases. Anthropologists study the evolution of human culture from hunting and gathering societies to complex, industrialized societies.

Most commonly, however, *evolution* refers to the formation and development of life on earth. The idea that all living things evolved from simple organisms and changed through the ages to produce millions of species is known as the *theory of organic evolution.* Most people call it simply the *theory of evolution.*

The French naturalist Chevalier de Lamarck proposed a theory of evolution in 1809. But evolution did not receive widespread scientific consideration until the late 1850's, when the British naturalist Charles R. Darwin presented his theory of evolution. Since then, advances in various scientific fields have resulted in refinements of the theory. The main ideas of evolution, however, have remained largely unchanged.

This article discusses the main ideas of evolutionary theory and the scientific evidence that supports the theory. For information about other types of evolution, see the *World Book* articles on **Universe** (Changing views of the universe) and **Earth** (History of Earth).

Main ideas of evolutionary theory

The theory of evolution consists of a set of several interrelated ideas. The basic idea states that species undergo changes in their inherited characteristics over time. There are two main types of change in organic evolution: *anagenesis* and *cladogenesis.*

Anagenesis refers to changes that occur within a species over time. Because of anagenetic change, the forms and traits of many species today differ from the forms and traits of their ancestors. Cladogenesis refers to the splitting of one species into two or more descendant species. This branching process, also called *speciation,* can be repeated to create many species. Current evolutionary theory holds that all species evolved from a single form of life which lived more than $3\frac{1}{2}$ billion years ago. Over time, repeated speciation events and anagenetic changes have produced the more than 10 million species inhabiting the earth today.

Related to speciation is the idea of *common ancestry.* Because all organisms evolved from one basic life form, any two species once had a common ancestor. Closely related species share a more recent common ancestor, but distantly related species must trace their ancestry far into the past to find a common ancestor. For example, human beings, chimpanzees, and gorillas evolved from a common ancestor that lived between 4 million and 10 million years ago, while the common ancestor of human beings and reptiles lived about 300 million years ago.

Other ideas relate to the tempo of evolutionary change. *Gradualism* is the idea that some evolutionary changes occur continuously over long stretches of time.

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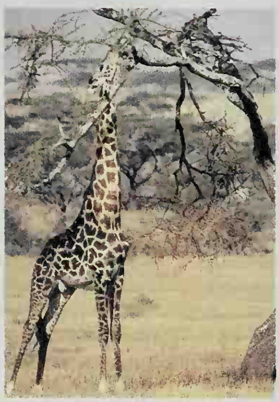

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Evolution has enabled living things to adapt to different environments. The thick trunk of a baldcypress anchors the tree in a swamp, while sea anemones cling to rocks in a tide pool. A hummingbird's long bill enables it to sip nectar from flowers. A tortoise is adapted to life in a desert, and a long-legged giraffe can reach the tallest trees on an African plain.

Punctuated equilibrium is the idea that some evolutionary changes take place in relatively short periods, from tens to hundreds of generations, followed by longer periods of little change called *stasis.* Both gradual and punctuated patterns can occur for different traits. The theory of evolution holds that evolution continues today at rates comparable to those of the past.

Still another idea is *natural selection,* a process by which the individuals better suited to their environment tend to leave more descendants. All living organisms must compete for a limited supply of food, water, space, mates, and other things they need to successfully reproduce. Scientists use the term *fitness* to refer to an individual's overall ability to reproduce.

Although evolution is called a "theory," this term does not mean that evolutionary biology is guesswork or is not supported by evidence. In science, a *theory* is a set of ideas based on observations about nature that explains many related facts. The theory of evolution is supported by evidence from many scientific fields. When a theory is supported by so much evidence, it becomes accepted as a scientific fact. Almost all scientists consider the theory of evolution to be a scientific fact.

Many people, however, reject the theory of evolution because of their religious beliefs. They believe the theory conflicts with the Biblical account of the Creation, which they interpret to mean that all forms of life were created essentially as they exist today.

Causes of evolutionary change

Much evolutionary change results from the interaction of two processes: (1) *mutation* and (2) *natural selection.* Mutation produces *random* (chance) variation in the biological makeup of a species or a *population*—that is, individuals of the same species living in the same area. Natural selection sorts out these random changes according to their value in enhancing reproduction and survival. Such selection ensures that variations which make individuals better adapted to their environment will be passed on to future generations. At the same time, natural selection eliminates variations that make individuals less able to survive. A third process called *genetic drift* also helps create evolutionary change.

Mutation is a permanent change in the hereditary material of an organism. By altering this material, a mutation may produce changes in an organism's traits. To understand how mutations produce these changes, one must understand how characteristics are inherited.

How characteristics are inherited. Hereditary characteristics of organisms are carried by threadlike structures called *chromosomes* in cells. Chromosomes carry large numbers of *genes,* the basic units of heredity. Genes consist of a substance called *DNA* (deoxyribonucleic acid). DNA contains the coded information that influences hereditary characteristics.

Among most animals and plants, each body cell has a

full set of paired chromosomes. Human body cells, for example, have 46 chromosomes arranged in 23 pairs. Offspring inherit half a set of chromosomes from each parent. Parents pass on their chromosomes to their offspring during sexual reproduction. Egg cells and sperm cells form in a special process called *meiosis* that gives them one chromosome at random from each pair of the parent's set. As a result, egg and sperm cells have half the number of chromosomes found in all other cells in the body. During reproduction, a sperm and an egg unite in the process called *fertilization,* and the fertilized egg then has the full number of chromosomes.

Sometimes, the genes from one of a pair of chromosomes change places with genes on the other pair as a sperm or egg cell forms. This change in the arrangement of genes, called *recombination,* can result in new combinations of inherited traits.

As the fertilized egg cell begins to grow, it also begins a process of division. Each chromosome in the nucleus of the cell duplicates itself. The chromosome and its duplicate lie next to each other in pairs. During normal cell division, called *mitosis,* one of each pair of chromosomes goes into each of two new cells. Thus, the new cells contain chromosomes that are identical with those in the original cell. This process of growth through cell division continues until it has produced all the cells that make up an organism.

How mutations change a species. Mutations may be caused by environmental factors, such as chemicals and radiation, which alter the DNA in genes, or by errors in the copying of DNA during cell division. After a gene has changed, it duplicates itself in its changed form. If these *mutant genes* are present in the egg or sperm cells of an organism, they may alter some inherited characteristics. Only such mutations can introduce new hereditary characteristics. For this reason, mutations are the building blocks of evolutionary change and of the development of new species.

Mutations occur regularly but are usually infrequent, and most of them produce unfavorable traits. *Albinism* is one such mutation. Albino animals have mutant genes that lack the ability to produce normal skin pigment. These animals do not survive and reproduce as well as normal animals. In most cases, such mutant genes are eliminated by natural selection because most individuals that inherit them die before producing any offspring.

Some mutations, however, help organisms adapt better to their environment. A plant in a dry area might have a mutant gene that causes it to grow longer roots. The plant would have a better chance of survival than others of its species because its roots could reach deeper for water. This type of beneficial mutation provides the raw material for evolutionary change.

Natural selection can involve any feature that affects an individual's ability to leave offspring. These features include appearance, body chemistry, and *physiology* (how an organism functions), as well as behavior.

For natural selection to operate, two biological conditions must be met. First, the individuals of a population must differ in their hereditary characteristics. Human beings, for example, vary in almost every aspect of their appearance, including height, weight, and eye color. People also differ in less obvious ways, such as brain size, thickness of bones, and amount of fat in the blood.

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Sexual selection has caused the evolution of features that give an animal an advantage in finding a mate. The colorful plumage of a peacock, *shown here,* helps it attract the female bird.

Many of these differences have some genetic basis.

The second requirement for natural selection is that some inherited differences must affect chances for survival and reproduction. When this occurs, the individuals with higher fitness will pass on more copies of their genes to future generations than will other individuals. Over time, a species accumulates genes that increase its ability to survive and reproduce in its environment.

Natural selection is a group process. It causes the evolution of a population or a species as a whole—not the evolution of an individual—by gradually shifting the average characteristics of the group over time.

There are several types of natural selection. They include (1) directional selection, (2) stabilizing selection, (3) balancing or diversifying selection, and (4) sexual selection.

Directional selection favors changes in traits that help a species adapt to its environment. Lizards called *anoles* provide an example of directional selection. These lizards live on many Caribbean islands. In the late 1900's, scientists moved populations of one anole species from their native habitat to several uninhabited islands. Some of these islands had little vegetation, and the lizards had to perch on twigs and small branches. Other islands had large trees. After just 10 to 14 years, the anoles on islands without large trees had evolved smaller hindlimbs, which gave them needed agility on their small perches. The anoles on islands with large trees developed longer hindlimbs, giving them the speed they needed to catch prey and avoid predators in their new habitat. These changes showed that anoles with shorter-than-average hindlimbs had left more offspring than average on islands without large trees. At the same time, anoles with larger-than-average hindlimbs had left more offspring than average on forested islands. Such natural selection helps species adapt to new environments by favoring more extreme traits. Over time, continued mutation and directional selection can produce species that differ significantly from their ancestors.

Stabilizing selection occurs if a species is already well adapted to its environment. In such cases, the individuals with average characteristics leave the most offspring,

and individuals that differ most from the average leave fewest. One example of stabilizing selection is the survival rate of human babies according to birth weight. Babies of average weight tend to survive better than those who are either heavier or lighter. Unlike directional selection, stabilizing selection eliminates extreme traits.

Balancing or diversifying selection occurs when natural selection maintains two or more alternative traits in the population. The gene that causes *sickle cell anemia,* a blood disease, provides an example of balancing selection. An individual who inherits the sickle cell gene from both parents may develop fatal anemia. But people who inherit the gene from only one parent do not get anemia and become more resistant to malaria, a common tropical disease. Thus, in areas threatened by malaria, the beneficial effects provided by a single copy of the sickle cell gene balance the harmful effects of inheriting two copies of the gene. Because of this balance, natural selection maintains the sickle cell gene in the population, along with the traits of both anemia and malaria resistance.

Sexual selection occurs primarily among animals. Adults of many species prefer mates who display certain behaviors or have certain external features. Over time, this process can lead to the evolution of complicated courtship rituals, bright coloring to attract mates, and other features. Sexual selection explains, for example, why males of many bird species have more-colorful feathers than do the females.

Genetic drift is a random change in the frequencies of genes in populations. It is caused by the random way that egg and sperm cells receive some chromosomes from each parent as they form. Because these reproductive cells contain only half a set of chromosomes, only half of a parent's genes exist in an egg or sperm. If the parents produce a limited number of offspring, some of their genes may not be passed on. Genetic drift alone does not enable species to adapt to their environment. However, just as random mutations may lead to evolutionary change, so may the random changes caused by genetic drift.

In small populations, genetic drift can bring about large evolutionary changes. For example, in Lancaster County, Pennsylvania, members of the Protestant Old Order Amish group have a high occurrence of Ellis-Van Creveld syndrome, a rare inherited disorder that causes people to become *dwarfs* (unusually small adults) with malformed hearts. These people are descendants of about 200 immigrants from Europe in the 1700's. A few of the immigrants probably carried the harmful trait. Biologists attribute the high frequency of this syndrome to genetic drift in the founding Amish population.

Evolution of new species

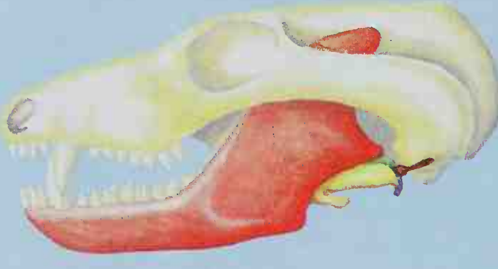
A *species* is a group of organisms that has become a *distinct evolutionary lineage*—that is, its members share critical adaptations required for successful reproduction. Various devices in nature maintain the distinct evolutionary lineages of species. In species that reproduce sexually, *reproductive isolating factors* play major roles. They include factors that prevent different species living in the same area from mating. For example, many spe-

The evolution of mammals from reptiles

WORLD BOOK illustrations by Oxford Illustrators Limited, adapted from illustrations by James A. Hopson and Claire Vanderslice

Dimetrodon (a reptile)
about 280 million years old

Procynosuchus (an early mammallike reptile)
about 250 million years old



Probainognathus (an advanced mammallike reptile)
about 235 million years old

The fossil record helps scientists learn about the evolution of mammals from reptiles. These illustrations, which are based on a number of fossils, show changes in the skull structure of intermediate animals called mammallike reptiles. The jaws of reptiles, such as *Dimetrodon,* had seven bones. The dentary bone, shaded red, became larger in mammallike reptiles and evolved into the single-boned jaw of mammals. Mammallike reptiles also evolved different types of teeth, such as molars and canines. These changes were accompanied by the development of larger, stronger jaw muscles, suggesting that these animals could chew food more thoroughly than reptiles. This chewing ability is characteristic of mammals.

cies of birds have unique courtship rituals, and females of one species will not respond to the male courtship of other species. If mating does occur between species, such matings may produce offspring that cannot survive or reproduce. A mule, for example, is the offspring of a female horse and a male donkey, and it is sterile.

Many species remain distinct even though they can interbreed and produce fertile offspring. In northwestern California, the Western sword fern has adapted to moist, shady habitats, while the narrowleaf sword fern has adapted to sites with drier soil and higher levels of light. Ferns reproduce by means of tiny cells called *spores,* which can blow in the wind for long distances. These California sword fern species live close enough to each other to interbreed and produce hybrids. Although the hybrids are fertile, they do not successfully reproduce in the Western sword fern's habitat or in the narrowleaf sword fern's habitat. Thus, natural selection favors keeping only one type of fern in each habitat, preserving the distinctiveness of each species.

Many biologists believe *speciation,* or the evolution of a new species, often begins when a species is separated into two or more geographically isolated groups. The geographic isolation of land species may result from the movement of continents over millions of years or from the division of habitats by glaciers, rivers, and other features. The rise of land bridges, such as the Isthmus of Panama, may separate marine species.

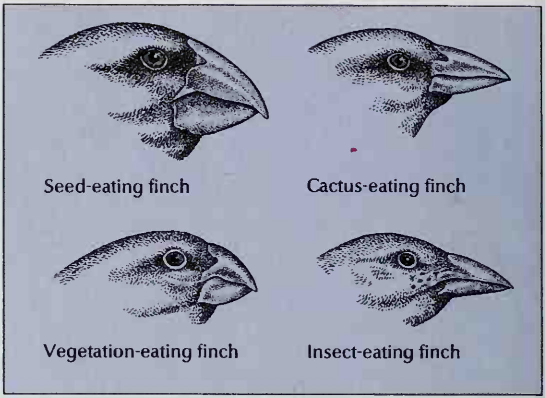
Over time, isolated populations evolve in different ways because their environments differ and because genetic drift and different mutations occur in each population. If geographic isolation lasts long enough, the populations may grow so dissimilar that each becomes adapted to a completely different environment, or the populations develop reproductive isolating factors and lose the ability to breed with each other. In either case, the populations have thus become distinct species.

Speciation sometimes takes millions of years, but it often occurs more rapidly. Rapid speciation is especially likely after a species settles in a new habitat, such as an unpopulated island. The founding population often experiences genetic drift and becomes subject to strong new forces of natural selection, such as a different climate or food supply. Occasionally, a major increase in the number of chromosomes, called *polyploidy,* can give rise to a new species. One form of polyploidy called *allopolyploidy* commonly occurs in plants and can give rise to new species within two generations.

Evidence of evolution

Evidence of evolution comes from observations of sources that document or indicate the occurrence of evolution. These sources include the fossil record, the geographic distribution of species, embryology, vestigial organs, and comparative anatomy. Evidence of evolution also comes from directly observing evolving populations and from artificial selection.

The fossil record provides some of the strongest evidence of evolution. Most organisms preserved as fossils were buried under layers of mud or sand that later turned into rock. Scientists determine the age of fossils by means of *potassium-argon dating, uranium-series dating,* and other dating methods. In such methods, researchers estimate how old the fossils are by measuring the amounts of certain *radioactive isotopes* (unstable forms of chemical elements) that they contain.



WORLD BOOK illustrations by Patricia J. Wynne; adapted from *Darwin's Finches* by David Lack, used with permission of Cambridge University Press

Specialized adaptations in finches on the Galapagos Islands resulted from competition for limited food. Different groups of finches developed beaks adapted to various kinds of food. After many generations, these groups evolved into separate species.

The fossil record has many gaps because relatively few species were preserved. Nevertheless, *paleontologists* (scientists who study prehistoric life) have found enough fossils to form a fairly complete record that documents much of the history of life on earth.

The fossil record shows a progression from the earliest types of one-celled life to the first simple, multicelled organisms, and from these organisms to the many simple and complex organisms living today. Fossils found in ancient layers of rock include the simplest forms of life. They differ greatly from many organisms that exist today. Fossils in recently formed layers of rock include complex as well as simple forms of life and are more similar to living plants and animals. Thus, the fossil record shows that many species became extinct, and that the species alive today have not always lived on earth.

The fossil record also documents many examples of continuous evolutionary change and speciation. A famous example is the evolution of mammals from reptiles. The fossil record contains no mammals before 250 million years ago but has many species of reptiles from that period. Mammals first appear as fossils about 200 million years ago. Between these two periods, scientists have found many remains of *transitional forms,* animals with characteristics of both modern mammals and modern reptiles. The skeletons of the first mammallike reptiles are nearly identical to those of reptiles, but later skeletons resemble those of mammals. In between occur creatures with a mixture of skeletal characteristics of reptiles and mammals. The transition from reptiles to mammals is so gradual that scientists cannot fix an exact point when reptiles became mammals.

Geographic distribution of species, also known as *biogeography,* provides important evidence for the theory of evolution. Certain island groups, called *oceanic islands,* arose from the sea floor and have never been connected to continents. The species found on oceanic islands are those that can travel easily, particularly over large stretches of water. These islands are rich in flying insects, bats, birds, and certain types of plants that float-

ed to the islands as seeds. But oceanic islands lack many major types of animals and plants that live on continents. For example, the Galapagos Islands have no native amphibians or land mammals. These animals cannot easily migrate from continents to islands.

In addition, the majority of species found on oceanic islands are most similar to those on the nearest mainland, even if the environment and climate are different. The Galapagos Islands, for instance, lie off the coast of mainland Ecuador in South America. The islands are much drier and rockier than the coast, which has a humid climate and lush tropical forests. But the plants and birds on the Galapagos Islands more closely resemble those of the wet, tropical coast than they do the plants and birds of other arid islands. This suggests that the first species to inhabit the Galapagos Islands came from South America rather than originating on the islands.

Oceanic islands contain a far smaller variety of species than do continents, and some island species are found nowhere else. The Galapagos Islands, for example, have 21 native species of land birds. Of these, 13 species are finches—a much higher proportion of finches than exists on any continent. The finches developed as different species partially because they ate different foods. They thus evolved specialized beaks and other adaptations for their different eating habits. These finch species live only on the Galapagos Islands. Therefore, the distribution of species supports the idea that a limited number of species came to the islands from the nearest mainland and then evolved into new species.

Embryology is the study of the way organisms develop during the earliest stages of life. The embryonic development of many organisms includes peculiar events that can be explained by the evolution of the organism from another species. For example, a mammal embryo forms three different pairs of kidneys in succession during its development. The first two pairs of kidneys perform no function and break down and disappear shortly after they form. The third kidney pair then takes shape and develops into the mature, functioning kidneys of the mammal. In an embryo of a fish, amphibian, or reptile, however, one of the first two types of kidney pairs becomes the animal's mature kidneys. These events suggest that mammals have retained some developmental features of their evolutionary ancestors. Scientists call this phenomenon *recapitulation.*

Vestigial organs are the useless remains of organs that were once useful in an evolutionary ancestor. For example, many species of animals that live in caves are blind but still have eyes. Some species have nearly complete eyes but lack an optic nerve, while others have tiny, malformed eyes. Some cave-dwelling crayfish have eyestalks but no eyes. They evolved from ancestors with functioning eyes. Because eyes are useless in a dark habitat, and may indeed be harmful if they are injured, mutations that damaged the vision of these species did not decrease their fitness. Thus these species lost their sight over time.

Comparative anatomy is the comparison of anatomical structures in different organisms. Such comparisons often indicate how evolution occurred. For example, the forelimbs of amphibians, reptiles, birds, and mammals all have a similar bone structure. This similarity suggests that these animals evolved from a common ancestor.

Direct observation of evolution is commonplace because much evolutionary change occurs rapidly. Scientists have observed both *anagenesis* (evolution within species over time) and speciation.

An important example of observed anagenesis involves the virus HIV-1. The virus gradually weakens the immune system in most infected individuals, eventually leading to AIDS, the final, life-threatening stage of HIV infection. The virus uses a protein to bind to human proteins and infect human cells. Two major types of the protein exist, called the *nonsyncytium inducing* (NSI) form and the *syncytium inducing* (SI) form. The SI form, which is more lethal to the cells it infects, can evolve from the NSI form through two simple mutations. Almost all new HIV-1 infections start with the NSI form, which is better adapted to healthy human immune systems. As the virus gradually weakens the patient's immune system, however, natural selection favors the SI form. Once the SI form has become common in an infected patient, the person usually dies from an illness that takes advantage of the body's weakened immune system. This frightening example of anagenetic change has occurred millions of times in AIDS patients.

Scientists have also directly observed speciation in

New species may evolve rapidly. The anomalous sunflower, *far right,* probably developed from a cross of the common sunflower, *below left,* and the prairie sunflower, *below right,* after only a few generations. An anomalous sunflower shares traits of both ancestral species. For example, the leaf bracts under its petals have the longer shape of the prairie sunflower's bracts and the hairiness of the common sunflower's.

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Artificial selection has caused dramatic changes in species. Plant breeders used artificial selection to produce broccoli, cabbage, cauliflower, and kohlrabi, *shown,* from a single species.

the laboratory. One important study involved the anomalous sunflower, which grows in the southwestern United States. Researchers found that this species evolved from hybrids of two other sunflower species, the common sunflower and the prairie sunflower, after only a few generations. By crossbreeding the common and prairie sunflowers in the laboratory, researchers produced, on several different attempts, hybrid species genetically similar to the anomalous sunflower.

Artificial selection. Animal and plant breeders use a method similar to natural selection to produce new varieties. Breeders commonly breed only the individuals in a species that show desired characteristics. This process, called *artificial selection,* eventually leads to large changes in a species. For example, the various breeds of dogs differ widely in size, appearance, and behavior. They probably descended, however, from one dog species and were bred to develop various traits. Many of these traits helped the dog perform a specific job, such as hunting badgers or herding sheep.

Plant breeders developed most food crops from wild ancestors by the same process. For example, cabbage, broccoli, kohlrabi, cauliflower, and Brussels sprouts all belong to a single species that was selectively bred to evolve different characteristics.

Artificial selection differs from natural selection only because human beings—instead of the natural environment—determine which characteristics give individuals an advantage in reproduction. The ability of artificial selection to cause dramatic changes in a short time leaves little doubt that natural selection could cause larger changes over the vast spans of earth's history.

History of the theory of evolution

Early theories. Two French naturalists, Comte de Buffon and Baron Cuvier, conducted some of the first scientific investigations of evolution in the 1700's. They concluded from their studies of fossils and living animals that life on earth had undergone a series of changes. But neither Buffon nor Cuvier had any idea how long ago these changes had occurred.

In 1809, the French naturalist Chevalier de Lamarck formulated the first comprehensive theory of evolution. He observed that an animal's body parts could change during its lifetime, depending on the extent to which it used them. Organs and muscles that were often used became larger and stronger, but those that were rarely used tended to shrink. According to Lamarck, such acquired traits became hereditary. His theory of the inheritance of acquired characteristics influenced many scientists. Later discoveries in genetics disproved his theory.

Darwin's theory. In 1858, Charles R. Darwin introduced a theory of evolution that, in modified form, is accepted by almost every scientist today. It states that all species evolved from a few common ancestors by means of natural selection. Darwin further elaborated the theory in his book, *The Origin of Species* (1859), which became a best-seller. Alfred R. Wallace, another British naturalist, devised an identical theory that was introduced along with Darwin's. However, Darwin developed his theory much more thoroughly, and his work has become better known. The British zoologist Thomas Henry Huxley and others helped advance Darwin's work.

Darwin used three principal sources in developing his theory. These were (1) his personal observations, (2) the geological theory of the British scientist Sir Charles Lyell, and (3) the population theory of the British economist Thomas Robert Malthus. Darwin made many of his observations as a member of a scientific expedition aboard the H.M.S. *Beagle* from 1831 to 1836. The ship made stops along the coast of South America, and Darwin collected many specimens of plants and animals and wrote detailed notes.

Darwin was particularly impressed by the variety of species on the Galapagos Islands. He found striking differences not only between species on the islands and those on the mainland, but also among those on each island. Darwin's findings led him to reject the idea that all living things were created as they currently existed. He then searched for another explanation for the origin of species.

The theories of Lyell and Malthus influenced Darwin's ideas about the earth's history and the relationship between living things and their environment. Lyell's *Principles of Geology,* published in the early 1830's, stated that the earth had been formed by natural processes over long periods. Darwin wondered whether life on earth had also developed gradually as a result of natural processes. In 1798, Malthus wrote that the growth of the human population would someday exceed the food supply unless checked by such factors as war and disease. Darwin assumed that environmental factors also regulated the population of all other living things. He concluded that only the individuals most fit in their environment would tend to survive and pass on their characteristics to their offspring.

The synthetic theory was formulated during the 1930's and 1940's by a number of scientists, including four American biologists—Sewall Wright, George G. Simpson, Russian-born Theodosius Dobzhansky, and German-born Ernst W. Mayr—and two British geneticists, Ronald A. Fisher and J. B. S. Haldane. Their theory *synthesizes* (combines) Darwin's theory of natural selection with the principles of genetics and other sciences. Darwin had observed that the characteristics of organ-

isms may change during the process of being passed on to offspring. However, he could not explain how or why these changes took place because the principles of genetics were not yet known.

The genetic principles of variation and mutation filled this gap in Darwin's theory. Gregor Mendel, an Austrian monk, had discovered the principles of genetics in the 1860's. Mendel's findings remained unnoticed until the early 1900's, when the science of genetics was established. About 1910, the American biologist Thomas Hunt Morgan discovered that chromosomes carry genes. Morgan also described the process of recombination, in which chromosomes exchange genes among one another, producing new combinations of hereditary traits.

The creation of the synthetic theory did not lead to universal agreement on all details of evolution. For example, some scientists emphasized the importance of both genetic drift and natural selection in shaping adaptive evolution. But others felt that genetic drift did not play a meaningful role in adaptation. This and other controversies still exist within the synthetic theory.

Contributions from other scientific fields. Discoveries in other fields have enabled biologists to study evolutionary processes in far greater detail. Some of the major contributions have come from *molecular biology,* which deals with the genetic processes that underlie all evolution. In the 1940's, molecular biologists identified DNA as the substance in chromosomes that carries hereditary information. In the 1950's and 1960's, studies of DNA revealed much about its structure and its role in evolutionary changes. These studies have led scientists to believe that, at the molecular level, evolution occurs through changes in the DNA.

In the 1960's and 1970's, molecular biologists developed methods to determine partial sequences of DNA molecules. These genetic surveys revealed that virtually all species have much genetic variation in their *gene pools,* the genes collectively shared by the entire species or population. Scientists thus learned that genetic variation, the raw material of all evolutionary change, occurred in abundance.

At the same time, molecular biologists developed techniques to compare genes in different species. Such comparisons enabled biologists to determine the evolutionary histories of species more precisely. For example, scientists did not know whether the giant panda was more closely related to raccoons or to bears. But DNA analysis has led most scientists to think that the panda is more closely related to bears.

In the 1990's, molecular biologists developed techniques for recovering small amounts of DNA from some fossils. These techniques have enabled scientists to directly examine prehistoric genes in the laboratory. Because of such advances, biologists can more accurately test their ideas about specific aspects of evolution. For example, scientists compared DNA from fossils of early human beings called Neanderthals with modern human DNA. They found that, on average, the differences between Neanderthal DNA and modern human DNA were considerably greater than the differences between the DNA of any two populations of modern human beings. Such research shows how closely all modern human beings are related to one another genetically.

Developmental biology, the science of how a fertilized egg develops into an individual organism, has also contributed to evolution. Starting in the 1990's, developmental biologists found that a common set of genes controls basic aspects of development in different plants and animals. These aspects include the formation of body segments in animals as diverse as worms and human beings. Such findings imply that the abovementioned genes were present long ago in the common ancestors of most species, and have remained unchanged even while being used to construct diverse body plans.

Finally, the area of *paleontology* (the study of the fossil record) continues to contribute to our knowledge of evolution. During the 1900's, paleontologists discovered fossils that indicated life on earth was about 3 $\frac{1}{2}$ billion years old, far older than previously believed. Paleontologists also used fossil evidence to show that the earth's evolutionary history included several mass extinctions. For example, many scholars now believe that a collision with an asteroid led to a mass extinction that killed off the dinosaurs. This major extinction enabled mammals to become the world's dominant large-bodied animals.

Acceptance of evolution

Today, the theory of evolution is considered the most important fundamental concept in the biological sciences. Nearly all scientists accept it. However, large numbers of people opposed the theory when it was introduced. Many people still do not accept it today.

In Darwin's time, the theory of evolution was attacked by many scientists, religious leaders, and other groups. Biologists argued that the evolutionary concept of hereditary variations within species contradicted the theory of blending inheritance. According to this theory, which was popular during the 1800's, hereditary characteristics became mixed and diluted as the blood carried them from one generation to another.

By the early 1900's, discoveries in genetics and other fields had resolved virtually all the original scientific objections to evolution. But other philosophical or religious objections remained. Some Christian leaders denounced the idea of evolution because it conflicted with their interpretation of the Biblical account of the Creation and suggested that human beings had evolved from apelike ancestors.

In the United States, much of the controversy centered on whether evolution should be taught in schools. In the 1920's, some states passed laws that banned such teaching in the public schools. In 1925, John T. Scopes, a Tennessee high-school teacher, was convicted in the famous "monkey trial" of teaching Darwin's theory (see Scopes trial). Although Scopes's conviction was later overturned because of a legal error, few public schools included evolution in the biology curriculum for many years after the trial.

In 1968, the Supreme Court of the United States ruled that laws banning the teaching of evolution were unconstitutional. The ruling stated that such laws made religious considerations part of the curriculum and thus violated the First Amendment to the Constitution. During the 1970's and 1980's, many religious groups proposed legislation that would require evolution to be taught along with an opposing view called *creationism.* Creationists believe that each species has remained relatively unchanged since the Creation and that no species has

evolved from any other. *Strict creationists* accept the Bible's account of the Creation as literal truth. They believe the earth is only thousands of years old. They also hold that all species were created simultaneously and that much of early life was destroyed by a global flood.

In 1981, Arkansas became the first state to enact a law requiring public schools to teach creationism whenever evolution is taught. However, a federal court declared this law unconstitutional before it went into effect. The court ruled that creationism constituted a religious and not a scientific explanation of life. Therefore, the court held that the Arkansas law violated the separation of church and state guaranteed by the First Amendment.

Because of these court decisions, opponents of evolution have largely abandoned their efforts to obtain laws banning its teaching. However, such opponents have turned their attentions toward influencing local school boards to reduce or eliminate the teaching of evolution in biology classes.

Since the late 1900's, a number of people have tried to combine aspects of evolutionary theory and creationism. One of the most prominent theories to come out of this effort is the *intelligent design theory.* It states that the earth is in fact billions of years old, rejecting a literal interpretation of the Bible. But it also argues that an "intelligent designer," similar or equal to the Biblical God, must have played a role in the origin of life and the development of different living species.

Many people—including some Christians, Muslims, and Orthodox Jews—still do not accept the theory of evolution because it conflicts with their religious beliefs. Many others, however, accept the basic principles of evolution within the framework of their religion. For example, some people interpret the story of the Creation as a symbolic and not a literal account of the origin of life. They find this symbolic interpretation compatible with evolutionary biology. For many, the idea that human beings evolved from other forms of life does not diminish the uniqueness of human capabilities and the achievements of human civilization. Alan R. Templeton

Related articles in *World Book* include:

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Darwin, Charles R.	Lamarck, Chevalier de	Spencer, Herbert
Earth	Lyell, Sir Charles	Teilhard de Chardin, Pierre
Fiske, John	Malthus, Thomas Robert	Wallace, Alfred R.
Fossil	Mutation	Weismann, August
Genetics (Population genetics)	Natural selection	

Outline

I. Main ideas of evolutionary theory

II. Causes of evolutionary change
- A. Mutation
- B. Natural selection
- C. Genetic drift

III. Evolution of new species

IV. Evidence of evolution
- A. The fossil record
- B. Geographic distribution of species
- C. Embryology
- D. Vestigial organs
- E. Comparative anatomy
- F. Direct observation of evolution
- G. Artificial selection

V. History of the theory of evolution
- A. Early theories
- B. Darwin's theory
- C. The synthetic theory
- D. Contributions from other scientific fields

VI. Acceptance of evolution

Questions

What evidence of evolution do fossils provide?
What are reproductive isolating factors? How are they important to the evolution of new species?
How does natural selection affect the characteristics of species?
What are some of the forms of natural selection?
How does mutation introduce new inherited characteristics?
What is genetic drift?
What three main sources did Charles Darwin use in formulating his theory of evolution?
How have studies of DNA advanced the theory of evolution?
What is an example of a vestigial organ?
What is recapitulation?

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Ewe. See Sheep.

Ewell, *YOO uhl,* **Richard Stoddert** (1817-1872), was a Confederate general in the American Civil War. He led a division under General Stonewall Jackson in the Shenandoah Valley campaign of 1862, distinguishing himself in battles at Winchester, Strasburg, and Cross Keys. Also in 1862, he aided Jackson in the defense of Richmond, Virginia, and fought in the Battle of the Seven Days. Ewell participated in the Battle of Cedar Mountain and in the Second Bull Run campaign (also called Manassas).

At Groveton, Virginia, on Aug. 28, 1862, Ewell was wounded and lost a leg. Ewell returned to duty as a lieutenant general in May 1863, though he had to be lifted to his horse and strapped in the saddle.

Ewell then commanded the Second Corps, formerly led by Jackson. Ewell took the corps through the Pennsylvania campaign and played a controversial role in the battle of Gettysburg, Pennsylvania, in July 1863. Several of his subordinate officers thought he should occupy Cemetery Ridge. Ewell, apparently taking literally General Robert E. Lee's orders to occupy Gettysburg, refused to seize Culp's Hill (near Cemetery Ridge) on the first day. As a result, Union troops took the hill and used it to anchor the right end of their line. Ewell finally tried to capture the hill but failed.

In 1864, Ewell led his corps in the battles of the Wilderness and Spotsylvania Court House. Later that year, he commanded the Richmond defenses. When Lee gave up the defense of Petersburg, Virginia, and Richmond in 1865, Ewell took charge of the remnant of a corps. That year, during the retreat toward Appomattox, Virginia, Ewell's corps was captured at Sayler's Creek, Virginia.

Ewell was born in Washington, D.C., of Virginia parents. He graduated from the United States Military Academy and fought gallantly in the Mexican War (1846-1848). Although he favored the Union, Ewell went with the South when Virginia withdrew from the United States in 1861. Steven E. Woodworth

Ex parte Milligan, *ehks PAHR tee,* was a legal case in which the Supreme Court of the United States ruled that civilians cannot be tried by military courts if civil courts

are available. This ruling, made in 1866, was one of the most important in the history of American civil liberties. It defined the limits of military power over civilians in wartime.

During the American Civil War (1861-1865), a military court in Indiana convicted Lambdin Milligan of cooperating with Confederate forces. Milligan appealed to the Supreme Court to determine if he was being justly imprisoned. The Supreme Court ruled unanimously that the military court, authorized by the president, was illegal because civil courts were open nearby. Milligan was freed from prison. The Supreme Court also ruled, by a 5 to 4 majority, that if civil courts are open, not even Congress can create military courts to try civilians.

Stanley I. Kutler

Ex post facto is a Latin term meaning *from what is done afterwards.* An *ex post facto* law is one that not only will make a particular act a crime from the time it is passed, but will also punish any person who has already committed the act. In many countries, legislators have had the power to pass such laws. Today, ex post facto laws are almost universally condemned. The Constitution of the United States and state constitutions prohibit such laws. Paul C. Giannelli

Excalibur, *ehk SKAL uh buhr,* was the sword of King Arthur, a legendary British ruler of medieval times. There are two versions of how Arthur got the sword. In one version, which probably originated in Robert Boron's *Merlin* (about 1200), Excalibur was embedded in a block of stone or in an anvil. Only the rightful heir to the throne of England could pull it out. Only Arthur succeeded, proving his right to be king.

Another version of the legend is found in the *Suite du Merlin* (about 1230). In it, Arthur received the sword and its valuable scabbard, which protected the bearer from injury, from the mysterious Lady of the Lake. She lived in a castle at the bottom of a magic lake. Just before Arthur died, he commanded a knight to throw Excalibur into the lake. When the knight did so, a hand rose from the water and pulled it down. The two versions of the legend are combined in Sir Thomas Malory's *Morte Darthur* (1470). Edmund Reiss

See also **Literature for children** (picture: Great illustrators of the 1900's).

Exchange rate is the price of one nation's currency expressed in terms of another country's currency. An American who buys a product from a company in the United Kingdom might have to pay for it in British pounds. The American would exchange dollars for pounds at the current exchange rate. For example, if the rate were $1.25 to the pound, the American would pay $25 for a British sweater that cost 20 pounds. If Americans bought more British products, the demand for pounds would increase and the pound would rise in price against the dollar. Thus, if the pound were to rise to $1.50, the American would have to pay $30 for the sweater.

From the late 1800's to the early 1900's, most major trading nations had their own fixed exchange rates under a system called the *international gold standard.* The governments of nations on the gold standard guaranteed to redeem their currency for a specified amount of gold. In the early 1900's, for example, the dollar was valued at about 26 grains (1.7 grams) of gold, and the pound at about 126 grains (8.2 grams). The exchange rate of the pound was thus fixed at about $4.85.

Most nations abandoned the gold standard during the 1930's and adopted a system called *pegging* after World War II ended in 1945. Under this system, a government bought and sold enough U.S. dollars in exchange for its own money to keep the exchange rate steady. If the Japanese yen fell, the Japanese government used its reserves of U.S. dollars or other international money to buy yen. The resulting increase in demand for yen caused the price to climb again, keeping the exchange rate pegged at the desired level.

Since the early 1970's, the major trading countries have had *floating exchange rates.* With such rates, the price of a nation's currency rises and falls in relation to world demand for that currency. Actually, however, most governments intervene if the exchange rate for their currency rises or falls too far. For this reason, the system is often called *managed floating.*

People buy and sell foreign currency through banks and special brokerage firms. The current price of a currency is called the *spot rate.* Banks and brokers also buy and sell contracts for the future delivery of currency at a price called the *forward rate.* Many newspapers publish daily reports on the spot and forward rates of major currencies. Robert M. Stern

Related articles in *World Book* include:

Balance of payments	European Monetary System
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Devaluation	Gold standard
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Excise is a tax on the manufacture, sale, or use of goods or services levied by local, state, or national governments. It is usually levied on one or a few products. But the taxed party usually adds the amount of the tax to the price of the goods or services, making the buyer the real taxpayer. Many cities and states place a general tax called a *sales tax* on the sale of all products (see **Sales tax**). Excise taxes also include fees paid for business licenses. Most excise tax revenue comes from the sale of tobacco, alcohol, and gasoline. Vito Tanzi

Exclamation point. See **Punctuation.**

Excommunication is the most severe penalty a religious body can impose on a member. It is used only for the most serious violations of the religion's rules. The penalty varies with the religion. In some religions, an excommunicated person is barred from any of the religion's ceremonies. A religion may also prohibit other members from associating with the excommunicated individual.

The procedure for excommunication differs according to the religious body and the nature of the offense. Some excommunications take the form of a declaration by a congregation, minister, or bishop. Others result automatically when the individual breaks certain rules of the religion. For example, Roman Catholics are automatically excommunicated if they physically attack the pope or become a heretic. Jill Raitt

See also **Middle Ages** (The power of the church).

Excretion. See **Elimination.**

Execution, in civil law, see **Debt.** In criminal law, see **Capital punishment.**

Executive, *ehg ZEHK yuh tihv,* is the branch of government that enforces the laws. The United States Constitu-

tion divides the work of government into three parts, *legislative, executive,* and *judicial.* Congress has the duty of legislation, or passing laws; the courts have the duty of judging; and the United States president is the chief executive, who carries out the laws. The individual states divide the work of government in a similar way, with the governor as executive.

In a monarchy, a king or queen today typically serves as a symbolic head of state. The true executive is usually a prime minister who serves as head of government.

Kenneth Janda

See also **Cabinet; Governor general; President.**

Executive order, in United States law, is an official direction, proclamation, or statement issued by the president. Executive orders carry the force of law, even though they do not require congressional approval. The president's power to issue executive orders is an *implied power*—that is, it is not specifically mentioned in the Constitution. However, it is considered necessary for effective government. Although the term *executive order* is mainly used in the United States, leaders of many other constitutional democracies have similar powers.

President George Washington issued the first executive order in the United States in 1789. It instructed the heads of government departments to make a "clear account" of matters in their departments. One of the most famous executive orders was the Emancipation Proclamation, issued by Abraham Lincoln in 1863. It declared freedom for all slaves in the areas then under Confederate control. In 2001, President George W. Bush issued a series of executive orders aimed at eliminating terrorist organizations in the United States and abroad.

Executive orders can be controversial, because they allow the president to make policy changes while bypassing legislative processes set forth by the Constitution. Some executive orders have been challenged or overturned by Congress or in court. Michael A. Genovese

See also **President of the United States.**

Executor, *ehg ZEHK yuh tuhr,* is a person who is named in a will to carry out the provisions of the will. Some people die without leaving a will, or without naming an executor if they do leave a will. In such cases, a probate court appoints an *administrator* in place of an executor. An administrator's duties are the same as those of an executor.

An executor's chief duty is to handle and dispose of the *estate* (money and other property left by the dead person). A probate court supervises the executor's handling of the estate. The executor must offer the will for *probate.* Probate is a court process in which probate court judges determine whether a will is legally valid. The executor pays all taxes and claims against the estate. Then the executor pays the *legacies* (inheritances) provided for in the will.

Executors file a report on their management of an estate with the probate court. Executors may take the cost of their expenses and the fee for their services out of the money in the estate. They are paid at rates that are set by law. They usually make a money pledge called a *bond,* in which they agree to perform their duties honestly.

Any adult who is sound in mind and of good reputation may be an executor. Many wills name as executor a member of the deceased person's family. Such executors often serve without compensation. Banks serve as the executors of many wills. The executor typically hires an attorney to assist in administering the deceased person's estate.

A person may refuse to act as executor. But a person who accepts the job and later wishes to give it up must get a court's permission to do so. William M. McGovern

See also **Administrator; Estate; Probate; Will.**

Exercise. See **Physical fitness.**

Exercise stress test. See **Stress test.**

Exile, *EHG zyl,* is banishment from one's own land. A person who has been punished by being exiled is called an *exile.* Exile was a common form of punishment for crimes and political offenses in ancient Palestine, Greece, and Rome. Civil wars often resulted in exile for leaders of the losing side.

In modern times, many countries have sent criminals and political offenders to distant parts of their realms. Thus, the United Kingdom sent convicts to the American Colonies and Australia in order to provide a source of labor to develop the new lands. In the mid-1900's in the Soviet Union, criminals and political offenders were sent in great numbers to work in Siberia. Most exiles of the present day are people who fled from their own countries because they were threatened by the tyrannical governments there. The Constitution of the United States prohibits the exile of a U.S. citizen. However, a noncitizen can be deported from the United States back to his or her country of origin.

The homesickness of the exile is a favorite theme of literature. In the Bible, Cain, sent to wander over the face of the earth, cries out that his punishment is more than he can bear. Many poets have spent part of their lives in exile and have expressed their longing for their home. Anthony D'Amato

Eximbank. See **Export-Import Bank of the United States.**

Existentialism, *EHG zihs TEHN shuh lihz uhm,* is a philosophical movement that developed in continental Europe in the 1800's and 1900's. It is called *existentialism* because most of its members are primarily interested in the nature of *existence* or *being,* by which they usually mean *human existence.* Although the philosophers generally considered to be existentialists often disagree with each other and sometimes even resent being classified together, they have been grouped together because they share many problems, interests, and ideas.

Existentialism grew out of the work of two thinkers of the 1800's: Søren Kierkegaard, a Danish philosopher and Protestant theologian, who is generally considered the movement's founder, and Friedrich Nietzsche, a German philosopher. Edmund Husserl, a German philosopher not usually considered an existentialist but the founder of his own movement, *phenomenology,* was nevertheless one of the greatest influences on existentialism.

The most prominent existentialist thinkers of the 1900's include the French writers Albert Camus, Jean-Paul Sartre, and Gabriel Marcel; the German philosophers Karl Jaspers and Martin Heidegger; the Russian religious and political thinker Nicolas Berdyaev; and the Jewish philosopher Martin Buber.

What is existentialism?

Existentialism is largely a revolt against traditional European philosophy, which reached its climax during the

late 1700's and early 1800's in the impressive systems of the German philosophers Immanuel Kant and Georg Wilhelm Friedrich Hegel. Traditional philosophers tended to consider philosophy as a science. They tried to produce principles of knowledge that would be objective, universally true, and certain. The existentialists reject the methods and ideals of science as being improper for philosophy. They argue that objective, universal, and certain knowledge is an unattainable ideal. They also believe this ideal has blinded philosophers to the basic features of human existence. The existentialists do not make the traditional attempt to grasp the ultimate nature of the world in abstract systems of thought. Instead, they investigate what it is like to be an *individual* human being living in the world.

The existentialists stress the fact that every individual, even the philosopher or scientist seeking absolute knowledge, is only a limited human being. Thus, every person must face important and difficult decisions with only limited knowledge and time in which to make these decisions.

For the existentialists, this predicament lies at the heart of the human condition. They see human life as being basically a series of decisions that must be made with no way of knowing conclusively what the correct choices are. The individual must continually decide what is true and what is false; what is right and what is wrong; which beliefs to accept and which to reject; what to do and what not to do. Yet, there are no objective standards or rules to which a person can turn for answers to problems of choice because different standards supply conflicting advice. The individual therefore must decide which standards to accept and which ones to reject.

The existentialists conclude, therefore, that human choice is *subjective,* because individuals finally must make their own choices without help from such external standards as laws, ethical rules, or traditions. Because individuals make their own choices, they are *free;* but because they freely choose, they are completely *responsible* for their choices. The existentialists emphasize that freedom is necessarily accompanied by responsibility. Furthermore, since individuals are forced to choose for themselves, they have their freedom—and therefore their responsibility—thrust upon them. They are "condemned to be free."

For existentialism, responsibility is the dark side of freedom. When individuals realize that they are completely responsible for their decisions, actions, and beliefs, they are overcome by *anxiety.* They try to escape from this anxiety by ignoring or denying their freedom and their responsibility. But because this amounts to ignoring or denying their actual situation, they succeed only in deceiving themselves. The existentialists criticize this flight from freedom and responsibility into *self-deception.* They insist that individuals must accept full responsibility for their behavior, no matter how difficult. If an individual is to live meaningfully and *authentically,* he or she must become fully aware of the true character of the human situation and bravely accept it.

The existentialists believe that people learn about themselves best by examining the most extreme forms of human experience. They write about such topics as death and the shadow it casts on life; the difficulty, if not the impossibility, of maintaining satisfactory relationships with other people; the ultimate futility and absurdity of life; the terrifying possibility of suicide; the alienation of the individual from society, nature, and other individuals; and the inescapable presence of anxiety and dread. This concentration upon the most extreme and emotional aspects of experience contrasts sharply with the main emphasis of contemporary philosophy in England and the United States. This philosophy focuses upon more commonplace situations, and upon the nature of language rather than experience.

The influence of existentialism

Several leading existentialists have expressed their ideas in novels, poems, short stories, and plays. The existentialists feel that philosophy should not be divorced from art. They believe philosophy is more like art and less like science than most other philosophers have believed. Moreover, the existentialists have involved themselves in social and political disputes. They believe that it is the responsibility of all persons to *engage* in these disputes and *commit* themselves to a side.

Existential theologians do not try to base religion on rational demonstration. They argue that the problem of religious belief is not a problem involving proof or disproof, but a decision, which, like other human decisions, must be made separately by each individual in the absence of conclusive evidence. The existentialist's interest in religion is primarily an interest in human religious experience. Ivan Soll

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Berdyaev, Nicolas	Kierkegaard, Søren A.
Camus, Albert	Nietzsche, Friedrich
Heidegger, Martin	Sartre, Jean-Paul

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Exobiology is the branch of biology that specializes in the search for and study of life elsewhere in the universe. Most scientists believe life on earth developed as a natural result of the physical and chemical reactions that occurred during the earth's formation and early development. Exobiologists use this belief as their main guide in the search for life on other planets.

Laboratory experiments suggest that the essential molecules that led to living organisms combined in the atmosphere and accumulated on the coastlines of oceans early in the earth's history. Eventually, the first organism capable of reproducing was formed and ultimately developed into complex systems of life. But exactly how this happened is unknown. Exobiologists seek to test the laboratory model for the origin of life on earth by looking for life on other planets. If such life is ever discovered, comparisons with life on earth could provide much new understanding.

Exobiologists try to predict where living organisms might have developed and survived. But they also study environments in which prebiological chemical reactions are occurring. Their investigations include astronomical observations, the results of planetary exploration by

space probes, and the application of basic scientific fields, such as *organic chemistry* (chemistry that involves the element carbon). Exobiologists also study fossil records to find the oldest evidence of life on earth in an effort to understand the conditions under which life began.

Scientists have developed instruments that can perform chemical and biological experiments on other planets. The instruments then send the results to the earth for analysis.

In 1976, two United States Viking space probes landed on Mars and conducted experiments. But these experiments did not uncover any living organisms. In 1996, scientists claimed they found evidence of Martian life from a meteorite discovered in Antarctica. This meteorite, which scientists believe came from Mars, is over 3.6 billion years old. It contained objects resembling fossils of bacteria. The meteorite also contained compounds that are produced by living organisms on the earth. Although the question of life on Mars remains unsettled, most scientists consider it very unlikely.

Exobiologists also are interested in attempts to receive intelligent radio signals from space by means of *radio telescopes*. Such signals would indicate the existence of advanced civilizations elsewhere in the galaxy.

Tobias C. Owen

Exodus is the second book of the Bible. The preceding book, Genesis, introduces the story of the Israelite people. But the actual history of Israel as a nation begins in Exodus. The book presents the idea of a God who brings freedom to the downtrodden and forms a lasting relationship with them. Although God and the Israelites are central to Exodus, the Israelite leader Moses is the main character in the book. Moses serves as a link between God and Israel, and he dominates the events in the book.

The word *exodus* comes from an ancient Greek term that means *going out*. The book's first 19 chapters describe the Exodus, in which the Israelites departed from Egypt, where they had been slaves. They traveled to Mount Sinai and entered into a *covenant* (agreement) with God. At Mount Sinai, God gave Moses the Ten Commandments (20:2-17) and a set of laws known as the Book of the Covenant (20:22 through 23:33). The last section of the book (chapters 25-40) deals with the construction of the *Tabernacle* (sanctuary) built by Moses and the Israelites.

The narrative of the Exodus includes two hymns in verse, the Song of Moses (15:1-18), and the Song of Miriam (15:21). The songs may date back to the time of the historical Exodus event, which probably took place in the early 1200's B.C. Carol L. Meyers

See also **Bible; Ten Commandments; Tabernacle; Moses.**

Exorcism, *EHK sawr sihz uhm,* is the act of breaking the power of the Devil or other evil spirits that influence or control a person's actions. Exorcism presupposes the existence of the Devil as an evil force in the lives of human beings.

The Devil's influence has many degrees. He can tempt a person to do something wrong, such as lie or commit a crime. He can even dominate an individual by temporarily taking control of the person's body.

When an evil spirit takes control of an individual or of an individual's actions, the person is said to be *possessed*. A possessed person may go into convulsions, acquire extraordinary strength, or shout curses—with no apparent explanation. Sometimes the evil spirit affects objects near the possessed person. For example, the spirit might cause objects to fly through the air. An evil spirit also could take control of a room or of an entire building.

Possession is difficult to verify because the phenomenon could result from causes other than evil spirits. For example, a supposedly possessed person might really be suffering a mental or physical illness.

Some Christian denominations and other religions have ceremonies for driving out devils and evil spirits. The New Testament tells that Jesus Christ exorcised devils. Jesus also gave His apostles the power to drive out devils. In the Roman Catholic Church, an exorcism is a ceremony that consists of a series of prayers recited over the possessed person.

In the A.D. 200's, the church established the office of *exorcist*, one who performs an exorcism. Priests hold this office but require a bishop's permission to perform an exorcism. The church's sacrament of baptism and the blessing of holy oil and holy water include prayers that ask God for protection from attacks by devils.

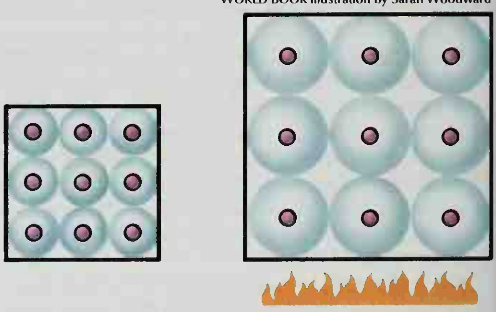
Francis T. Hurley

Expansion is an increase in the size of a body without the addition of material to the body. Most solids and liquids expand when they are heated and contract when they are cooled. Gases also expand when they are heated at a constant pressure. They naturally expand to fill their containers. If a gas is heated in a container that prevents expansion, the pressure of the gas increases (see **Gas** [How gases behave; Gas laws]).

Expansion

The illustration below shows how heat causes molecules, in red, to force themselves farther apart.

WORLD BOOK illustration by Sarah Woodward



Heat causes expansion because it increases the vibrations of a material's atoms or molecules. In a gas, heat also increases the speed at which the atoms or molecules move about. The increased movement forces the atoms or molecules farther apart and the body becomes larger.

Different materials expand by different amounts when their temperature is raised by one degree. For example, aluminum expands twice as much as iron under the same temperature increase. John B. Butt

See also **Heat** (Changes in size).

Expansionism. See **Imperialism.**

Granger Collection

Exploration has greatly increased knowledge of the world through the centuries. The map above provides a record of the world as Europeans knew it in the 1500's. The photograph below shows how part of the world actually looks from space.

NASA

Exploration

Exploration is one of the oldest and most widespread of human activities. People in all times and places have engaged in some form of exploration. Even children explore their immediate surroundings.

However, the people we usually think of as explorers are those individuals who traveled over long distances and to unfamiliar areas for certain purposes. For example, some explorers have sought to learn more about an unknown part of the world or have traveled for adventure. Others have hoped to gain fame or wealth for themselves or to expand their country's trade or territory. Still others have set out on expeditions to faraway lands for religious reasons.

In many cases, as explorers came upon places that were new to them, they encountered people who had been living in these areas for centuries. When Europeans began arriving in the Americas in the late 1400's, for example, they found the continents to be inhabited by the people who are now commonly called American Indians. Sometimes, the inhabitants helped explorers by acting as interpreters and providing information about geography and sources of food and water. More frequently, explorers tried to conquer or colonize newly found lands. In many cases, fighting broke out between the new arrivals and the local peoples.

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People have engaged in exploration since prehistoric times. Prehistoric human beings crossed vast areas of land and water and eventually populated all the continents except Antarctica. Later navigators started out from the islands of Southeast Asia and settled Hawaii, New Zealand, and other Pacific Islands.

In ancient and medieval times, people from Europe, the Middle East, and Asia ranged far beyond their homelands to chart many areas new to them. Even so, as late as 1450, large parts of the world remained isolated from one another. Starting about that time, Europeans became the most active explorers in the world. They eventually explored the Americas, Siberia, the Pacific Islands, Australia, Africa, the Arctic, and Antarctica. By the early 1900's, most parts of the world had been explored and mapped. At that time, explorers turned their attention to two new frontiers—the ocean depths and space.

The first explorers

Most scholars believe that the earliest human beings originated in southern and eastern Africa. These early people and their nearest descendants are often considered the first explorers. They traveled far from their original homelands, settled Africa, and spread across Asia and Europe as well.

During the last ice age, from about 100,000 to 11,500 years ago, sea levels were lower than they are today, and several areas now separated by water were joined together. For example, what are now New Guinea and Australia formed a single continent. As early as 50,000 years ago, the first seafaring explorers sailed from Southeast Asia to colonize these lands. Somewhat later, people from northeast Asia entered what is now Alaska. They traveled across a land bridge that connected North America and Asia where a waterway called the Bering Strait separates the two continents today. Scholars disagree on when human beings first crossed into the Americas and where they settled. However, by 10,000 years ago, people could be found in nearly all parts of North and South America.

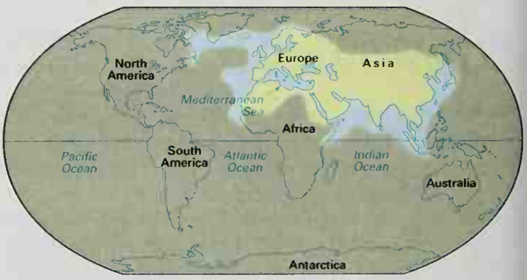
At least 3,000 years ago, people from the islands of Southeast Asia set out on the first of many voyages on the Pacific Ocean. These seafarers sailed over long stretches of water in double canoes without the help of sophisticated navigational instruments. But they did have knowledge of the stars for navigation. They eventually settled Fiji, Hawaii, New Zealand, Samoa, Tahiti, Tonga, and other Pacific Islands. A few scholars believe that these early sailors discovered new islands by accident. But many others think that the early Pacific seafarers planned their voyages of exploration and colonization.

Ancient exploration

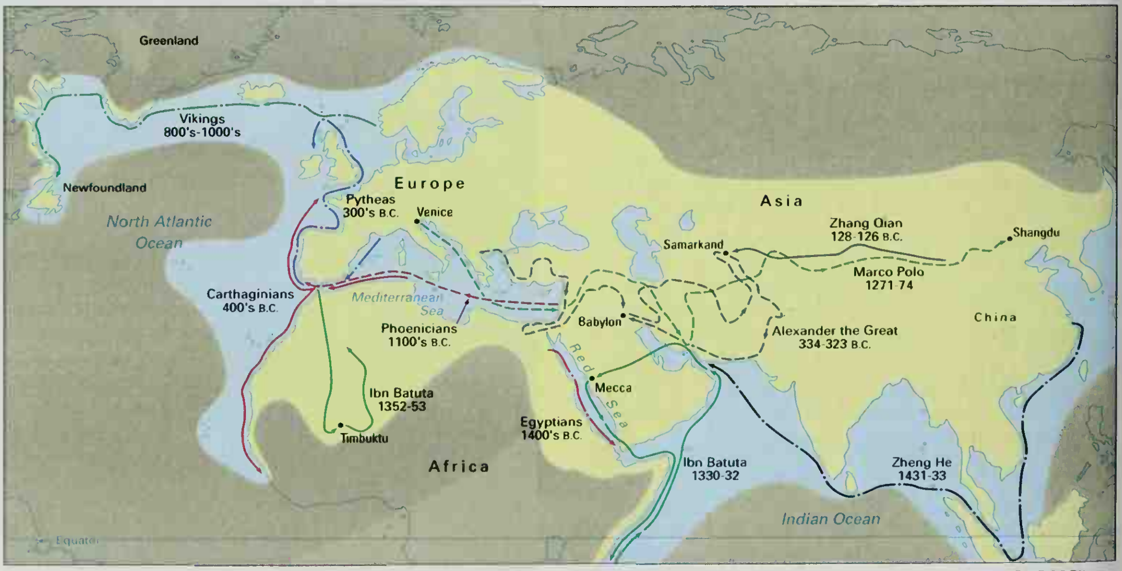
Ancient people living in the Middle East and along the shores of the Mediterranean Sea explored parts of Europe, Africa, and Asia. In the late 1400's B.C., Queen Hatshepsut (pronounced *hat SHEHP soot)* of Egypt sent an expedition by way of the Red Sea to a place called the

Ancient and medieval exploration

The map at the right shows how much of the world's lands (yellow) and seas (blue) were known to Europeans by the A.D. 1300's. The enlargement below shows the routes of some ancient and medieval expeditions, beginning with the Egyptian exploration of the 1400's B.C.—one of the first ever recorded.



Egyptians 1400's B.C.
Phoenicians 1100's B.C.
Carthaginians 400's B.C.
Alexander the Great 334-323 B.C.
Pytheas 300's B.C.
Zhang Qian 128-126 B.C.
Vikings 800's - 1000's
Marco Polo 1271-74
Ibn Batuta 1330-32, 1352-53
Zheng He 1431-33



WORLD BOOK maps

Land of Punt. The exact location of Punt is not known. It may have been in southwest Arabia or the Somali coast of Africa.

Granger Collection

Alexander the Great of Macedonia expanded ancient Greek knowledge of the world.

The Phoenicians, whose main cities were on the coasts of what are now Israel, Lebanon, and Syria, sailed far into the Mediterranean Sea to conduct trade and establish colonies. About 500 B.C., the Carthaginian statesman and navigator Hanno set out with 60 vessels on an expedition that took him down the west coast of Africa, perhaps as far as what is now Sierra Leone or the Gulf of Guinea.

The Greeks expanded geographical knowledge by founding colonies, especially in Asia Minor, Italy, and southern France, and along the coast of the Black Sea. The Greeks were also the first people to write about past exploration and to describe the world as it was known to them. Herodotus *(hih RAHD uh tuhs),* the great Greek historian of the 400's B.C., included much geographical information in his account of the war between the Persians and the Greeks.

One of the most important Greek explorers was Pytheas *(PIHTH ee uhs).* During the 300's B.C., he sailed up the coasts of Spain and France and around the British Isles. He then probably entered the North Sea. Pytheas mentioned a land called Thule *(THOO lee),* which was probably Norway. For many years, people in the Mediterranean region considered Thule to be the farthest inhabited part of the world to the northwest.

Also in the 300's B.C., Alexander the Great launched a military campaign that greatly expanded the world known to the Greeks. Alexander was the son of King Philip II of Macedonia, a country north of Greece. Philip had defeated the Greeks and formed a union between Greece and Macedonia. After Alexander succeeded his father, he set out to expand Macedonian and Greek power.

In 334 B.C., at the age of 22, Alexander led his army into what is now Turkey. Soon after, he won a victory over the Persian army. The young king then marched south to conquer Egypt. Next, he fought his way across western Asia, conquering Babylonia, Persia, and much of present-day Afghanistan. Soon after crossing the Indus River in what is now Pakistan, Alexander's soldiers refused to go any farther. He and his men then sailed down the Indus to the Indian Ocean. Alexander and part of the army returned to the Middle East by land. But Nearchus *(nee AHR kuhs),* one of his officers, sailed from the mouth of the Indus to the Persian Gulf.

The Chinese. The most significant Chinese expeditions in ancient times were undertaken from 138 to 109 B.C. by Zhang Qian (pronounced *jahng chee ehn,* and also spelled Chang Ch'ien). Zhang traveled in the service of the Emperor Wudi (Wu-ti), who wished to develop diplomatic relations with people in western Asia. Zhang traveled as far as the river valley of the Amu Darya. This river flows into the Aral Sea in what is now Uzbekistan. Although Zhang's missions were not a diplomatic success, his reports expanded Chinese ideas of the world. They also laid the foundation for later trade between China and the Roman Empire, especially in silk.

The Romans. The Roman Empire reached its greatest extent about A.D. 100, when it stretched from Britain through much of Europe and the Middle East, and across Egypt and the rest of northern Africa. The Romans did not engage in much exploration. Through trade, however, they acquired information about some areas beyond their empire, such as the east coast of Africa and the Indian Ocean. Much of what was known about the world in ancient times was preserved in the writings of Ptolemy *(TAHL uh mee),* a geographer and astronomer who lived in Egypt during the 100's.

Medieval exploration

After the collapse of the western Roman Empire in the late 400's, Europe was divided into small kingdoms and other states. For about the next 600 to 800 years, most Europeans had neither the means nor the desire to engage in exploration. During this same period, Muslims—that is, followers of the religion of Islam—established a huge empire that eventually extended throughout the Middle East and across northern Africa. Many Muslims became expert navigators. Muslim merchant ships with *lateen* (triangular) sails ranged throughout the Indian Ocean, going as far as East Africa and Southeast Asia.

By about the 1200's, the Chinese and Europeans had a renewed interest in exploration. By that time, explorers could find their direction more easily because of the development of the magnetic compass. Some scholars believe that the Chinese were the first to use the compass for navigation about 1100 and that it was quickly adopted by Muslims and northern Europeans. Others believe that Muslims and northern Europeans independently developed the use of the compass for ship navigation.

Granger Collection

A medieval Muslim map of the world shows Arab lands at the top. This map accompanied *The Book of Roger,* a geographical treatise completed by the Muslim explorer al-Idrisi in 1154.

Viking exploration. The most important European explorers from the fall of the Roman Empire to about the 1000's were the Vikings, who originally came from Scandinavia. About 800, they settled the Shetlands, the Faroes, and other islands in the North Atlantic Ocean. About 860, a storm drove a Viking ship to a large island that was later named Iceland. The Norse began to settle Iceland about 870, and it became the base for later voyages.

About 900, Gunnbjorn Ulfsson, a Viking leader, sighted Greenland. About 982, Eric the Red began exploring the coast of this huge island. Eric and other Vikings later established colonies there.

About 986, another Viking leader, Bjarni Herjolfsson *(BYAHR nee hehr YOHLF suhn),* was driven off course while sailing from Iceland to Greenland. Herjolfsson sighted a coastline to the west—probably North America—but he did not land there. Instead, he went on to Greenland. About 1000, Leif Ericson, son of Eric the Red, led an exploring party to the land Herjolfsson had sighted. He set up a base at a place he called Vinland. No one knows exactly where Vinland was, but most believe that it lay in what is now the Canadian island of Newfoundland. Vikings made several other voyages to Vinland and established a colony there. But conflicts with the local peoples and other problems led the Vikings to abandon the colony about 1014.

Muslim exploration. Muslims studied the writings of ancient authorities and produced outstanding geographies and maps. During the 1100's, for example, al-Idrisi *(uhl ih DREE see)* traveled widely throughout the Middle East. After moving to the court of King Roger II of Sicily, al-Idrisi prepared an important geographical treatise, often called *The Book of Roger.* Completed in 1154, it surveyed all the countries of the world known to Europeans and Muslims of that time.

The most celebrated Muslim explorer was Ibn Battuta *(IHB uhn bat TOO tah),* who was born in Morocco. From 1325 to 1354, he traveled as far as India and China. He also visited the Mali Empire in western Africa south of the Sahara. His account of his travels is often called *Rihla (Journey).*

Chinese exploration. During the Middle Ages, Chinese explorers made long journeys throughout Asia and the Middle East. Until about the 1200's, most of these travels were religious *pilgrimages* (journeys to sacred places). The Buddhist monk Xuanzang (pronounced *shyoo an zahng,* and often spelled Hsuan-tsang), for example, set out in 629 for India, the birthplace of Buddhism. There, he visited many Buddhist holy places over a 16-year period and gathered much information about the history and geography of the region.

The largest Chinese expeditions took place during the early 1400's. From 1405 to 1433, Zheng He (pronounced *juhng huh,* and also spelled Cheng Ho) commanded seven expeditions involving dozens of ships. He sailed from the waters of the East China Sea to the Indian Ocean and to the East African coast. As a result of these voyages, China expanded diplomatic and commercial relations with more than 30 countries.

European exploration. During the mid-1200's, Europeans came into more direct contact with central and eastern Asia than ever before. At that time, most of Asia was ruled by the Mongols, a nomadic people who were superior fighters. European leaders hoped to convert the Mongols to Christianity and persuade them to become allies against Muslim rulers in the Middle East and northern Africa. In the 1240's and 1250's, several Franciscan friars, including John of Plano Carpini and William of Rubruck, visited the camp of the *khan* (Mongol leader) at Karakorum in what is now Mongolia. The friars failed to convert the khan to Christianity, but they brought back much information about eastern Asia.

The most famous European traveler in Asia in the 1200's was Marco Polo, a native of Venice. In 1271, when Marco was 17, he accompanied his father, Nicolò, and his uncle Maffeo to China. Nicolò and Maffeo Polo were merchants. They had visited China in the 1260's and had been well received by Kublai Khan, the Mongol emperor of China. During Marco's visit, he made such a favorable impression on Kublai Khan that the Mongol ruler sent him on official missions throughout the kingdom. After returning to Venice in 1295, Marco was taken prisoner during a conflict between Venice and Genoa. While in captivity, he dictated an account of his travels. This widely read book, called *Description of the World,* was the first to provide Europeans with detailed and accurate information about China's impressive civilization.

Granger Collection

The astrolabe was one of the most important navigational instruments on voyages of discovery. The astrolabe, along with the quadrant, enabled sailors to determine latitude more accurately.

The great age of European exploration

By the 1400's, many Europeans wanted to buy products that came from Asia—jewels, silk, and such spices as cinnamon, pepper, and cloves, which were used to season and preserve food. As the Mongol Empire had begun to break down into smaller states during the 1300's, overland trade between Asia and Europe became increasingly disrupted and expensive.

By the mid-1400's, Turkish Muslims controlled much of the main overland route between Europe and Asia, but overland trade was still uncertain. Muslims also controlled the sea trade routes from Asia to the Middle East. In the Mediterranean, the Italian city of Venice held a monopoly on trade in spices and eastern luxury goods between the Muslim ports and the rest of Europe. As a result, other Europeans became eager to bypass the old overland and Mediterranean sea routes and find a direct ocean route to the *Indies,* as Europeans then called the eastern part of Asia. Europeans also hoped to make converts to Christianity and thereby strike a blow against the Muslims.

Portugal and Spain took the lead in launching voyages to discover a direct ocean route to the Indies. By 1500, ship designers in these countries had made long voyages possible by designing a new kind of ship, known as the *caravel.* The caravel combined square sails with the triangular lateen sails used by Muslims. Exploration by sea was also aided by the use of the *astrolabe* and the *quadrant,* instruments that enabled sailors to determine latitude more accurately. The expeditions of Portugal and Spain opened a great period of exploration and led to the colonization of America by Europeans.

Reaching the tip of Africa. During the early 1400's, Portuguese explorers concentrated their attention on the west coast of Africa. Prince Henry, a son of King John I of Portugal, became known as Henry the Navigator. He never went on a voyage of exploration himself, but he encouraged and sponsored many explorations. Henry wanted to increase Portugal's trade along the African coast and find the source of the gold that African Muslim traders had been carrying north from central Africa for centuries. He also hoped to find a legendary Christian kingdom that was supposed to exist somewhere in Africa.

Trip after trip, Henry's crews sailed farther and farther south along the African coast. By the time Henry died in 1460, the coast had been traced as far south as present-day Sierra Leone. During these voyages, the Portuguese collected gold dust and African captives who were sold into slavery. After 1500, when the settlement of the Americas created a demand for slaves, other Europeans began to sail to the west African coast to take part in the slave trade.

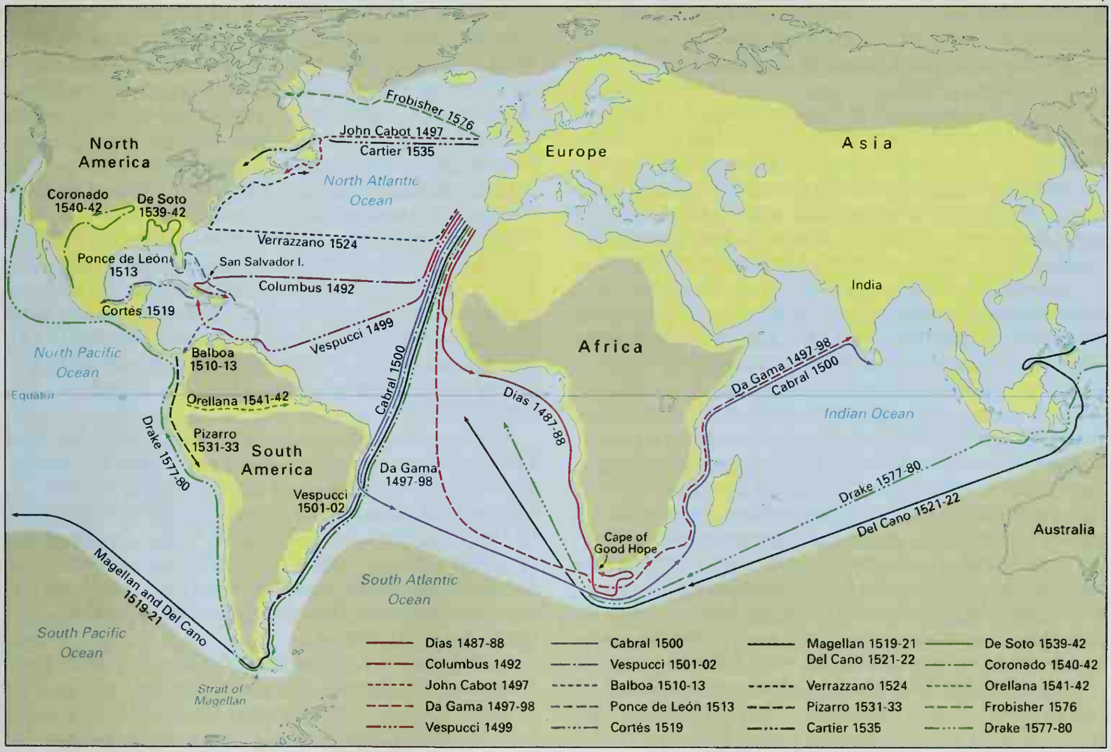
During the late 1400's, the Portuguese became increasingly hopeful of reaching the southern end of Africa. They believed that such a discovery would reveal a way of sailing to India.

In 1487, the Portuguese explorer Bartolomeu Dias *(BAHR tul uh MEH oo DEE uhs)* set out to find a route around Africa. As he sailed along the continent's southwestern coast, a violent storm blew his ships south of the tip of the continent. Dias then turned east and sailed into the Indian Ocean in early 1488 without sighting the tip of Africa. After turning north again, Dias reached the east coast of Africa, but his crew then forced him to return to Portugal. On the return voyage, he saw a point of

The great age of European exploration

European knowledge of the world greatly expanded during the 1400's and 1500's, as shown by the yellow and blue areas on this map. European explorers of the time sailed around Africa to Asia and began to map the Americas.

WORLD BOOK map



land jutting out from the continent's southern tip. The Portuguese named it the Cape of Good Hope because its discovery indicated hope that a sea route to India had been found.

Columbus reaches America. While the Portuguese were searching for an eastward sea route to Asia, Christopher Columbus, a sea captain from Genoa, looked to the west. Columbus developed a plan to reach Asia by sailing across the Atlantic Ocean. He was convinced that his plan would work. However, he underestimated the distance between western Europe and Japan—and he did not know that a large land mass lay in the way.

Columbus tried without success to persuade the Portuguese to give him command of a westward expedition. In 1485, he went to Spain. He eventually persuaded Queen Isabella to support his plan. He was given three small vessels: the *Niña,* the *Pinta,* and the *Santa María.* He assembled a crew of about 90 men and boys for the voyage.

Columbus left Palos, Spain, on Aug. 3, 1492. After a stop at the Canary Islands, off the west coast of Africa, the expedition headed westward across the Atlantic. The crew sailed for more than a month without seeing land. Finally, on October 12, an island was sighted.

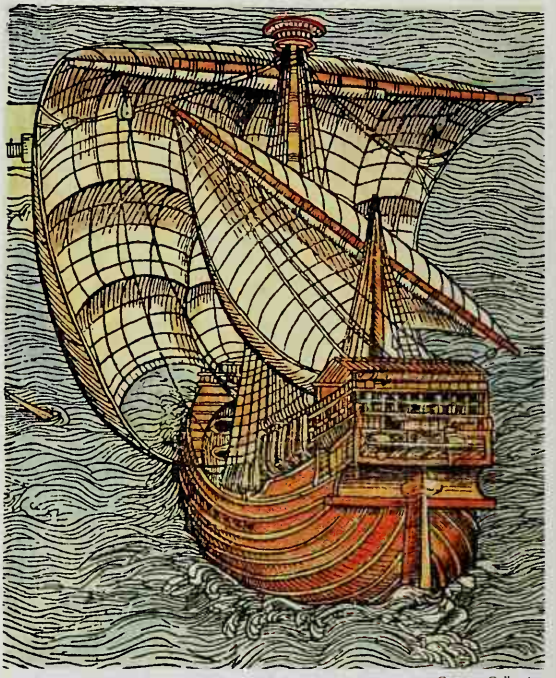
Columbus landed on the island, which is one of the Bahamas. He also visited two other islands—Cuba and Hispaniola (now shared by Haiti and the Dominican Republic). Columbus believed that he had reached the Indies, and so he called the people he met Indians. He started his return trip to Spain in January 1493 and reached Palos in March.

The voyage around Africa. News of Columbus's discoveries caused much excitement in Spain. But the Portuguese did not believe that Columbus had reached the Indies because he had not brought back spices or other known Asian products. They remained convinced that the best route to Asia would be found by sailing around Africa.

In 1497, King Manuel I of Portugal chose the Portuguese navigator Vasco da Gama *(VAHSH koo duh GAH muh)* to sail all the way to Asia. On July 8, da Gama set out from Lisbon, Portugal, with four ships and a crew of about 170. Instead of sailing close to the west African coast, he swung out into the Atlantic to find the most favorable winds. He rounded the Cape of Good Hope on November 22 and then sailed into the Indian Ocean. At Malindi, in present-day Kenya, he found an experienced Arab pilot, Ahmad Ibn Majid *(AHM ahd IHB uhn MAH jihd),* who agreed to show the way to India.

The Portuguese reached Kozhikode on the southwest coast of India on May 20, 1498. Kozhikode's Hindu ruler was not interested in the goods da Gama brought to trade. The Muslim merchants there were not happy to see da Gama, whom they considered a possible business rival. But the explorer obtained some gems and spices, including pepper and cinnamon, to take back to Portugal to prove he had reached Asia. Da Gama made a second voyage to Kozhikode in 1502. He arrived with a fleet of 20 ships, bombarded the town, and established Portuguese rule there. The Portuguese called the town Calicut, a variation of *Kalikat,* the town's Arabic name.

Exploring the New World. Columbus made three more voyages across the Atlantic from 1493 to 1504. He explored what are now Jamaica, Puerto Rico, and Trinidad, and the coasts of Venezuela and Central America. Columbus always believed that he had been in or near Asia, but it gradually became clear that he had come upon lands previously unknown to Europeans.



Granger Collection

The caravel was used by Spanish and Portuguese sailors for ocean exploration and trade during the 1500's and 1600's. Caravels combined square sails with triangular *lateen* sails.

In 1497, John Cabot, an Italian navigator, became the first European to visit the northeast coast of North America since the Vikings. Sailing in the service of King Henry VII of England, Cabot landed on the east coast of Canada or on the coast of Maine. Cabot's voyage helped lay the foundation of English claims to North America.

Other explorers began to visit South America. In 1500, two explorers independently reached the area where the Portuguese colony of Brazil would later be established. They were Vicente Yáñez Pinzón *(bee THEHN tay YAH nyehth peen THAWN),* a Spaniard who had commanded the *Niña* on Columbus's first voyage; and Pedro Álvares Cabral *(PAY throo AHL vuh reesh kuh BRAHL),* a Portuguese captain on his way to India. Pinzón also explored the mouth of what would later be called the Amazon River.

Amerigo Vespucci *(uh MEHR uh goh veh SPOO chee),* a merchant and navigator born in Italy, made two voyages along the eastern coast of South America from 1499 to 1502. He was the first person to refer to the lands he had visited as a "New World." In 1507, a German geographer placed a Latin version of Vespucci's first name—that is, *America*—on a map of the newly found southern continent. This name was later applied to North America as well.

In 1513, the Spanish explorer Vasco Núñez de Balboa *(VAHS koh NOO nyayth day bal BOH uh)* led an expedition across what is now Panama from its Atlantic coast to its Pacific coast. He became the first European to see the

eastern shore of the Pacific Ocean. His finding helped prove that the New World was indeed a huge land mass lying between Europe and Asia.

Magellan's globe-circling expedition. In 1517, Ferdinand Magellan *(muh JEHL uhn),* a Portuguese navigator, asked King Charles I of Spain to sponsor a voyage to Asia by way of South America. King Charles agreed because the Portuguese controlled the route around Africa. If Magellan was successful, Spain would have its own route to Asia. At the time, Magellan did not know how large South America is.

Magellan sailed from Spain on Sept. 20, 1519. He had five ships and a crew of about 240. After reaching the northeast coast of Brazil, he sailed southward until he arrived at what is now Puerto San Julián, Argentina. He spent several months there and farther south at what is now Puerto Santa Cruz, Argentina, during the Southern Hemisphere's winter.

Magellan set sail from Puerto Santa Cruz on Oct. 18, 1520. Three days later, the ships entered a passage now known as the Strait of Magellan at the southern tip of South America. On November 28, three of the five ships sailed out of the strait into the Pacific Ocean. One of the other two ships had been wrecked in a storm, and one had turned back to Spain.

In the Pacific, the explorers sailed for more than three months without sighting any land except two uninhabited islands. Food ran out, and the sailors ate oxhides and rats to stay alive. In March 1521, Magellan reached what is now Guam, where he was able to gather supplies. He then sailed to the present-day Philippine Islands. There, he became involved in a conflict among the islanders. Magellan was killed in a battle on April 27, 1521.

After Magellan's death, the expedition abandoned one of the ships. The other two sailed to the Spice Islands (now part of Indonesia). One of these ships, the *Victoria,* then sailed west under the command of Magellan's lieutenant, Juan Sebastián del Cano *(hwahn seh BAS tee AHN dehl KAHN oh).* The ship crossed the Indian Ocean and sailed around the Cape of Good Hope. Badly damaged and with only 18 Europeans and 3 or 4 Indonesians aboard, the *Victoria* reached Spain on Sept. 6, 1522, having completed the first trip around the world.

Spain's conquests in the New World. During the early 1500's, Spanish explorers pushed across most of Central and South America. They unintentionally brought with them smallpox and other diseases that were unknown in the Americas. As a result, thousands of Native Americans, who had no resistance to these diseases, sickened and died from them. The Spanish explorers established colonies in the new lands. Royal officials, Roman Catholic priests, and settlers arrived soon after the explorers. The Indians typically were forced to work for the Spaniards. The Spaniards also brought sugar cane, wheat, and other new plants to the Americas, as well as horses, cattle, sheep, and other domestic animals. The Spaniards took back to Europe many plants that were unknown there, such as corn and potatoes.

One of the most important Spanish expeditions in the New World was commanded by Hernando Cortés *(kawr TEHZ),* who left Cuba in 1519 with more than 600 men. He sailed to what is now the Mexican state of Yucatán, which was a center of Maya civilization. Cortés moved along the coast of Mexico and then inland to Tenochtitlan (now Mexico City), the capital of the Aztec empire. Along the way, he met an Indian woman named Malinche, who the Spaniards called Doña Marina. Malinche, who knew both the Maya and the Aztec languages, served as an interpreter for Cortés.


From the *Codex Duran* (1520); The National Library, Madrid (Granger Collection)
Spanish soldiers attacked Aztec Indians in 1520, *above.* The Spaniards and Indians fought many bloody battles as the Spaniards pushed across Central and South America in the 1500's.

By 1521, Cortés had subdued the Aztec and taken permanent control of their empire. Mexico then became a base for Spanish exploration of Central America and what is now the southern United States.

Several Spanish expeditions also explored and conquered much of South America. From 1527 to 1529, Sebastian Cabot, a son of John Cabot, explored one of the continent's great water systems by sailing up the Rio de la Plata and the Paraná and Paraguay rivers in present-day Argentina and Paraguay. Cabot was looking for a "white king" whose realm was supposed to be rich in silver. Other explorers searched for a fabulous golden kingdom in South America, especially in what are now Colombia and Venezuela. This kingdom was usually called *El Dorado,* which means "the gilded one."

In 1532 and 1533, the Spanish explorer Francisco Pizarro *(frahn SIHS koh pih ZAHR oh)* conquered the Inca Indians. From their home in what is now Peru, the Inca ruled an empire that included parts of what are now Colombia, Ecuador, Bolivia, Chile, and Argentina. From 1535 to 1537, Diego de Almagro *(DYAY goh deh ahl MAHG roh),* a member of Pizarro's party, explored parts of what are now Bolivia and Argentina and crossed the Andes Mountains into Chile. In 1541 and 1542, Francisco de Orellana *(frahn SIHS koh deh oh ray YAH nah),* another veteran of Pizarro's expedition, sailed from the Andes Mountains down the mighty Amazon River to its mouth on the Atlantic Ocean in Brazil.

During the 1500's, Spaniards explored much territory that became part of the United States. In 1513, Juan Ponce de León *(hwahn PAWN say day lay AWN)* sailed from Puerto Rico and landed on the east coast of Florida. He then sailed around the southern tip of Florida and into the Gulf of Mexico. He next explored the southwest coast of Florida before returning to Puerto Rico.

In 1539, an expedition of more than 600 people led by Hernando de Soto *(dih SOH toh)* sailed from Cuba to the west coast of Florida. In search of gold, this expedition traveled through what is now the southern United States, including Georgia, Alabama, Mississippi, and Arkansas. The explorers found no gold, but they became the first Europeans to reach the Mississippi River. After de Soto died of fever in 1542, the survivors of the expedition sailed down the river and eventually reached Mexico by way of the Gulf of Mexico.

In 1540, Francisco Vásquez de Coronado set out from Campostela near the west coast of Mexico on an expedition to find the legendary Seven Cities of Cibola. These supposedly rich and flourishing cities were thought to lie north of Mexico City. Coronado traveled through what are now Arizona, New Mexico, Texas, Oklahoma, and Kansas. He found no important cities, but his expedition and that of de Soto gave Europeans a good idea of the width of North America.

The search for a northern passage. During the 1500's, the known sea routes to Asia were long, and they were controlled by Spain and Portugal. As a result, Europeans from other nations tried to find alternate—and shorter—routes. Some explorers looked for a Northwest Passage—that is, a strait or other body of water that would allow ships to sail through North America to reach Asia. Others looked for a Northeast Passage north of Europe. However, none of the explorers of the time found a Northwest or Northeast Passage, and the search continued for centuries.

In 1524, King Francis I of France sent Giovanni da Verrazzano *(joh VAHN ee dah VEHR uh ZAH noh)*, an Italian navigator, to North America to find a passage to Asia. Verrazzano explored the east coast from about Cape Fear in present-day North Carolina to Newfoundland. But he did not find a passage.

Jacques Cartier *(zhahk kahr TYAY)*, a French explorer, also failed to find a passage during two voyages he made from 1534 to 1536. However, Cartier became the first European to see the St. Lawrence River in what is now Canada and helped establish French claims to this region.

Several English explorers also looked unsuccessfully for a Northwest Passage in North America. From 1576 to 1578, Martin Frobisher made three voyages and reached what is now Frobisher Bay in northeastern Canada. In 1585, John Davis, another English navigator, discovered and explored what are now Davis Strait between Greenland and Canada and Cumberland Sound in northeastern Canada.

English merchants sent three expeditions in search of a Northeast Passage from 1553 to 1580. However, these expeditions got only as far as the Kara Sea north of Russia before they turned back. Willem Barents *(WIHL uhm BAR uhnts)*, a Dutch navigator, looked for the Northeast Passage during the 1590's. He sailed farther north than any other European had in a recorded voyage and explored what is now Spitsbergen and other islands in the Arctic Ocean.

Linking the globe

By 1600, the Spanish had explored, and established colonies in, Central and South America and parts of North America. Spain tried to claim all of North America, but the French and English set up their own colonies and explored much of the continent themselves. Meanwhile, Russians were moving east to explore what are now Siberia and Alaska. During the 1700's and 1800's, European explorers gradually filled in the outlines of the areas that were still unknown to them. They mapped the Pacific Ocean, worked their way through the interiors of Australia and Africa, and reached the Arctic and Antarctic regions. Finally, in the 1900's, they raced to reach the North and South poles.

The French and English in North America. During the 1600's, the French and English began to found colonies in what are now Canada and the United States. The French and English, like the Spanish before them, unknowingly introduced smallpox and other new diseases into the areas that they controlled. As before, many Indians died from these diseases. The French and English also traded with the Indians for the skins of beaver and other animals. Traders learned much about the land from the Indians, who frequently acted as interpreters and guides.

Samuel de Champlain *(sham PLAYN)*, a French explorer and geographer, charted the Atlantic coast from Cape Breton Island in Canada to Martha's Vineyard in what is now Massachusetts. In 1608, he founded the city of Quebec as a fur-trading post. Over the next eight years,

WORLD BOOK map

The exploration of North America by Europeans in the 1600's and 1700's revealed the continent's shape and much of the interior. American explorers pushed westward in the early 1800's.

he traveled extensively and learned about the rivers and lakes of the region. In 1609, Champlain became the first European to reach the lake in present-day New York, Vermont, and Quebec that now bears his name.

The French also explored the great river known as the Mississippi. In 1673, Louis Jolliet *(lwee JOH lee eht),* a fur trader, and Jacques Marquette *(zhahk mahr KEHT),* a Roman Catholic priest, reached the river near what is now Prairie du Chien, Wisconsin. They paddled canoes southward to the place where the Mississippi meets the Arkansas River. In 1682, René-Robert Cavelier, Sieur de La Salle *(luh SAL),* led an expedition that sailed down the Illinois River. He began at a point near present-day Peoria, Illinois, and then traveled down the Mississippi to its mouth at the Gulf of Mexico. He claimed the entire region drained by the Mississippi for France and named it Louisiana in honor of King Louis XIV.

The first permanent English settlement in North America was founded at Jamestown, Virginia, in 1607. By the end of 1670, English settlements had been established in 12 of what were to become the 13 original colonies. The first permanent settlement in the 13th, Georgia, was founded in 1733.

England also claimed much of what is now eastern Canada. This claim was based in part on a voyage of the English navigator Henry Hudson, who was looking for a Northwest Passage. In 1610, Hudson sailed through a strait in northeastern Canada into a large body of water he thought was the Pacific Ocean. It was really a huge bay now known as Hudson Bay.

Crossing North America. During the 1700's, French and British explorers blazed new trails westward across the northern parts of North America. They also discovered the northern limits of the continent.

In 1738 and 1739, the French-Canadian fur trader Pierre Gaultier de Varennes, Sieur de La Vérendrye *(lah vay RAHN dree),* and his sons explored what are now Manitoba and North Dakota. In 1742 and 1743, two of the sons, Louis-Joseph and François, traveled as far as present-day Montana and Wyoming.

From 1770 to 1772, the British explorer Samuel Hearne explored the land north of Churchill, Manitoba, to the Coppermine River The Coppermine flows into the Arctic Ocean.

Alexander Mackenzie, an agent of a fur-trading company called the North West Company, made further explorations of northern North America. In 1789, he traveled north from the western tip of Lake Athabasca in present-day Alberta to the mouth of the river now named after him. In 1792 and 1793, he made a famous journey from Lake Athabasca across the Rocky Mountains to the Pacific Ocean.

Two U.S. Army officers, Meriwether Lewis and William Clark, began an important expedition to the Pacific Northwest in 1804. In May of that year, they set out from St. Louis and traveled up the Missouri River. They spent the winter with Mandan Indians near what is now Bismarck, North Dakota. There, they met Sacagawea *(sah KAH guh WEE uh),* a Shoshone woman who agreed to be their interpreter. The following spring, the expedition continued up the Missouri and crossed the Rockies. Once past the mountains, the explorers pushed to the Columbia River. They followed the river to the Pacific Ocean, reaching it in November 1805. Lewis and Clark returned to St. Louis in 1806. They brought back with them valuable information about the land, plant and animal life, and peoples they encountered on their journey.

The Russians in Siberia. The exploration of what is now called Siberia—the vast region in northern Asia between the Ural Mountains and the Pacific Ocean—began in 1581. That year, Yermak Timofeyevich *(yur MAHK ty-ihm uh FYAY uh vyich),* a Russian military leader, conquered the ruler of a territory called Sibir just east of the Ural Mountains. The name *Siberia* was then applied to the entire region.

During the early 1600's, Russians moved eastward across Siberia. They came upon Lake Baikal in 1643. By 1650, Russians had reached the Sea of Okhotsk in the northern Pacific and had rounded the Chukchi Peninsula in northeastern Asia. In the late 1690's, a Russian soldier named Vladimir V. Atlasov *(AT luh sawf)* conquered the peoples of the Kamchatka Peninsula on the Pacific coast of what is now eastern Russia.

In 1728, Vitus Bering *(VEE tus BAIR ihng),* a Danish seaman in the service of Russia, led an expedition that sailed from Kamchatka north through the strait now named after him. But he did not see North America because of dense fog. In 1741, Bering headed a larger expedition. He and his chief lieutenant, Aleksei I. Chirikov *(CHIHR yuh kuhf),* sailed on different ships. Both men saw the coast of Alaska. Bering also sighted what is now Mount St. Elias and landed briefly on Kayak Island. As a result of Bering's voyages, Russia claimed Alaska. In 1784, the Russians established the first European colony there, on Kodiak Island.

Exploring the Pacific. Several Spanish and English navigators had explored the Pacific after Magellan's voyage, but this vast ocean was still largely unknown to Europeans in 1600. In the 1600's and 1700's, Dutch, English, and French navigators sailed throughout the Pacific. They discovered many islands. European voyagers also hoped to find the mysterious *Terra Australis Incognita* (Unknown Southern Continent). The Europeans of the time believed this legendary large and fertile continent lay in the South Pacific as a counterweight to the northern continents of Europe and Asia.

After 1750, two developments made long Pacific voyages safer than they had been. First, sailors realized that lemons and other fresh fruits and vegetables would prevent *scurvy.* This disease, which is caused by a lack of vitamin C, had been responsible for many illnesses and deaths on earlier voyages. Captains now tried to have supplies of these foods on hand for their crews. Second, in the late 1700's, navigators began to use the *chronometer,* a device that enabled them to determine longitude more accurately. As a result, it was possible for them to pinpoint their position at sea and to establish the exact location of newly found islands.

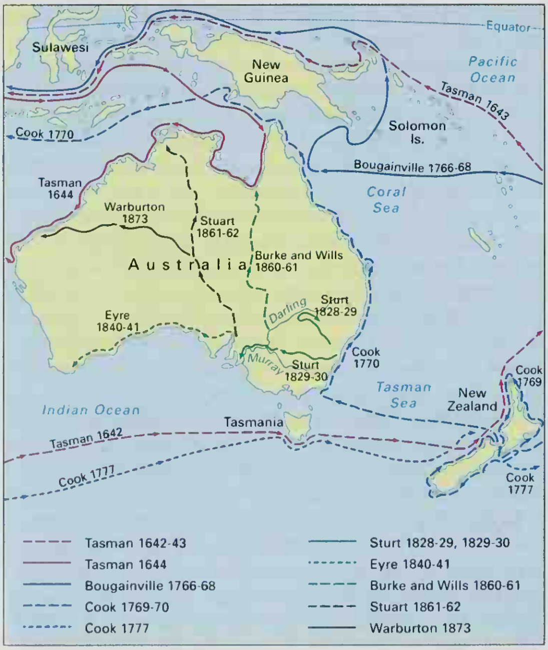
In the early 1600's, the Dutch began to establish control over what is now Indonesia. This strategically placed area became the starting point for Dutch voyages of exploration in the Pacific Ocean. From 1606 to 1636, Willem Jansz *(WIHL uhm YAHNS)* and other Dutch navigators reached the coast of Australia, but they did not establish colonies there. In 1642 and 1643, the Dutch navigator Abel Janszoon Tasman *(AH buhl YAHN sohn TAZ muhn)* reached the island now called Tasmania,

which is named after him, and sighted New Zealand. In 1644, he made a voyage during which he explored Australia's northern and western coasts.

During the second half of the 1700's, the French and the British were the most active in exploring the Pacific. In 1766, Louis-Antoine de Bougainville *(lwee ahn TWAHN duh boo gahn VEEL)* began what would be the first French voyage around the world. In January 1768, Bougainville entered the Pacific by way of the Strait of Magellan. In April, he reached the island of Tahiti, which had been visited the year before by Samuel Wallis, a British explorer. Bougainville's later account of the island's people and climate made Tahiti seem like an earthly paradise to many Europeans.

Bougainville was the first European to see several islands in the Pacific, including the island in the Solomon group now named after him. In addition, among Bougainville's crew was probably the first woman to sail around the world. This young Frenchwoman, named Jeanne Baret *(zhahn bah RAY)*, sailed with Bougainville disguised as a male servant to one of the scientists on the expedition. Her true identity was not revealed until after the expedition had reached Tahiti.

The greatest explorer of the Pacific was James Cook, a British naval officer who made three long voyages from 1768 to 1779. These voyages provided much scientific information about the waters and islands of the Pacific and contributed to European colonization of Australia and other territories. Cook's first voyage was mainly a scientific expedition, but Cook also had orders from the British Navy to try to find the Unknown Southern Continent. He did not find it, but he did explore New Zealand and the eastern coast of Australia.



WORLD BOOK map

The European exploration of Australia began with sea voyages that reached the area during the 1600's and 1700's. Explorers crossed the interior of the continent in the 1800's.

Cook was instructed to look for the Unknown Southern Continent during his second voyage as well. In 1773 and 1774, he crossed the Antarctic Circle and went farther south than any other explorer up to that time. But he could not find an Unknown Southern Continent. During his third voyage, Cook set out to look for an outlet of the Northwest Passage in the northern Pacific. In 1778, he sailed north through the Bering Strait until ice blocked his way. He found no outlet. The following year, Cook was killed in a dispute with the local peoples on the island of Hawaii.

Exploring Australia's interior. The exploration of Australia began soon after the British established a colony for convicts near what is now Sydney in 1788. The British often fought with the original inhabitants of Australia, who are known as Aborigines. In addition, thousands of Aborigines died from diseases unknowingly introduced by the Europeans. However, some Aborigines acted as guides and pointed out sources of food and water to explorers.

At first, exploration was centered on the areas around Sydney. In January 1829, an expedition led by Charles Sturt, a British Army officer, reached the Darling River. In 1829 and 1830, Sturt led a second expedition during which he sailed down the Murrumbidgee and Murray rivers to the sea near present-day Adelaide.

Exploration of the interior of Australia was difficult and dangerous because much of the region is desert. The British explorer Edward John Eyre (pronounced *air*) became the first European to make a major overland journey from east to west. His expedition in 1840 and 1841 closely followed the southern coast of Australia. The first European party to cross Australia from south to north was led by Robert O'Hara Burke, an Irish-born explorer; and William John Wills, a British-born explorer. Burke and Wills left Melbourne in 1860 and reached the Gulf of Carpentaria in 1861. On their return trip, they starved to death. Meanwhile, John McDouall Stuart, a Scottish-born explorer, was also trying to cross Australia. Stuart made several unsuccessful attempts before making a round trip between the southern and northern coasts in 1861 and 1862.

The exploration of Africa. By the late 1700's, Europeans were familiar with the coasts of Africa, but the interior of the continent remained a mystery to them. Penetration of the interior was difficult because of the harsh terrain in many places and the presence of deadly diseases, such as malaria and dysentery. Despite these obstacles, Europeans explored most of Africa south of the Sahara during the late 1700's and the 1800's. During the late 1800's, exploration was combined with conquest, and Europeans became the rulers of most of the African continent.

During the late 1700's and early 1800's, European explorers tried to solve a mystery that had puzzled geographers for centuries. Ancient writers had mentioned an important African river called the Niger. But they had not known where the river began, in what direction it flowed, and where it ended. In 1796, Mungo Park, a Scottish explorer, reached the Niger near Ségou, in what is now Mali. He determined that it flows from west to east. In 1830, Richard Lemon Lander, a British explorer, sailed down the Niger to its mouth in the Gulf of Guinea. During the 1820's, Alexander Gordon Laing, a Scottish

WORLD BOOK map

Exploring the interior of Africa. During the 1700's and 1800's, European expeditions explored the regions of the great rivers of Africa—the Congo, Niger, Nile, and Zambezi. Explorers also crisscrossed the western and southern parts of the continent.

Granger Collection

"Dr. Livingstone, I presume?" With those words, reporter Henry Morton Stanley, *left,* greeted explorer David Livingstone, *right,* at their famous meeting in 1871. Stanley went to Africa to find Livingstone, who had not been heard from for several years.

explorer, and René Caillié *(ruh NAY cah YAY),* a Frenchman, separately visited the city of Timbuktu, near the Niger in Mali.

By the late 1700's, Europeans were familiar with the lower Nile, which is formed by the meeting of the Blue Nile and the White Nile at what is now Khartoum, in Sudan. But the source of the river was a mystery. In 1770, James Bruce, a Scottish explorer, reached the source of the Blue Nile in the mountains of Ethiopia.

In 1857, the British explorers Richard Francis Burton and John Hanning Speke began to search for the source of the White Nile. In 1858, they reached Lake Tanganyika, which is now bordered by what are now Burundi and Tanzania in the east and Congo (Kinshasa) and Zambia in the west. Arabs in the region told Burton and Speke about another large lake nearby. Speke went alone to look at the lake and became convinced that it was the source of the Nile. He named it Lake Victoria in honor of Queen Victoria of the United Kingdom. This lake, known as Victoria Nyanza in Africa, lies partly in what are now Kenya, Tanzania, and Uganda.

Speke returned to Lake Victoria in 1862 and identified the source of the Nile as a large waterfall at the lake's northern end. This waterfall is now submerged by the Owen Falls Dam. Burton and others believed that Speke was wrong, but later explorers proved him right.

During the early 1860's, a British explorer named Samuel White Baker explored many rivers of eastern Africa with his companion, Florence, who later became his wife. In 1864, they became the first Europeans to reach what are now called Lake Albert (Albert Nyanza) and Murchison Falls.

The most famous European explorer in Africa was David Livingstone *(LIHV ihng stuhn),* a Scottish missionary. From 1854 to 1856, he became the first European to cross Africa. He followed the Zambezi River during part of his journey from what is now Angola to Mozambique. In 1855, he became the first European to see the Victoria Falls on the Zambezi River. In 1859, during a later expedition in southeast Africa, he reached Lake Nyasa, also known as Lake Malawi. From 1866 until his death in 1873, Livingstone explored the lakes and rivers of central Africa.

In 1869, Henry Morton Stanley, a reporter, received an assignment from the publisher of the *New York Herald* to go to Africa to find Livingstone. Livingstone had not been heard from in several years. The story of how Stanley found Livingstone near Lake Tanganyika in 1871 captured the imagination of people around the world (see **Stanley and Livingstone**). Stanley became an important explorer himself. From 1874 to 1877, he crossed central Africa from east to west and explored the Congo River. His explorations during the 1880's helped answer questions about the Congo and Nile rivers.

Arctic exploration. By 1800, a great deal was known about the Arctic regions because of the discoveries of early explorers. However, no one had as yet found either the Northwest Passage or the Northeast Passage. Dur-ing the 1800's, European explorers accomplished both of these goals. Attention then turned to reaching the North Pole.

The severe cold and ice of the Arctic made exploration there extremely dangerous. Ships could get trapped in ice or destroyed by it. Food was scarce, and starvation was a real danger if explorers used up their supplies.

In the early 1800's, the British Navy began to send expeditions to try to find a Northwest Passage in Arctic waters north of Canada. In 1819, William Edward Parry, a British naval officer, found an entrance to the Northwest Passage in the Canadian Arctic. He sailed through Lancaster Sound as far west as Melville Island.

In 1845, Sir John Franklin left England with two ships and 128 men to continue the search for the passage. By 1848, nothing had been heard from Franklin and his men. The British then began sending ships to look for them, but the remains of the expedition were not found until 1859. Franklin and his crew had died after their ships became jammed in the ice. From 1850 to 1854, Robert McClure, an officer in command of one of the search ships, traveled from the Bering Strait to the Atlantic Ocean. He claimed that he had found the Northwest Passage. But he had sailed on several ships and had gone part of the way on heavy sleds. As a result, it was not clear whether a single ship could make its way through the passage. This feat was accomplished from 1903 to 1906 when Roald Amundsen *(ROH ahl AH muhn suhn)*, a Norwegian explorer, sailed from the Atlantic Ocean to the Bering Strait.

Meanwhile, Nils Adolf Erik Nordenskjöld *(nihls AH dawlf AY rihk NOOR duhn SHOOLD)*, a Swedish explorer, completed the Northeast Passage from Europe to Asia. In July 1878, he sailed east from Tromsø, Norway, and reached the Pacific Ocean a year later.

During the late 1800's, many explorers tried to reach the North Pole. At first, many people believed that there was open water in the Arctic Ocean and that the North Pole might be reached by ship. It soon became clear, however, that the Arctic Ocean has a permanent cover of ice. As a result, explorers would have to cross the ice by sled to reach the pole.

From 1898 to 1905, Robert E. Peary, an American explorer, led two expeditions to try to reach the North Pole. He began his third expedition in 1908 and headed north to the pole from Ellesmere Island in the Canadian Arctic in early 1909. Peary is usually credited with reaching the North Pole on April 6, 1909, accompanied by his chief assistant, Matthew A. Henson, and four Inuit. Upon returning to the United States, Peary learned that another American explorer, Frederick A. Cook, claimed that he had reached the pole a year before Peary, on April 21, 1908. Most experts decided that Peary's story was more believable than Cook's, but the dispute has never been definitely settled.

The invention of the airplane and other technological advances in the 1900's brought new methods of polar exploration. In 1926, Richard E. Byrd, an American naval officer, and Floyd Bennett, an American pilot, claimed they flew from Svalbard to the North Pole and back in a three-engine airplane, though some scholars today dispute that claim. Also in 1926, a team of explorers flew from Svalbard to Alaska by way of the North Pole in an airship called the *Norge*. The explorers included Umberto Nobile *(um BER taw NOH bee lay)*, an Italian Air Force officer, who piloted the craft; Lincoln Ellsworth, an American civil engineer; and Roald Amundsen, who had earlier sailed through the Northwest Passage. In 1958, the U.S. nuclear-powered submarine *Nautilus* passed underneath Arctic ice to the position of the North Pole.

The exploration of Antarctica. By the early 1800's, Antarctica remained the only continent still unknown to the world. But this uninhabited frigid continent was difficult to reach and explore because it is surrounded by stormy, ice-filled waters and is covered by a thick layer of ice.

Nobody knows who first saw the Antarctic continent. But many historians divide the credit among three individuals known to have sighted Antarctica on separate voyages in 1820. These three are Edward Bransfield, a British naval officer; Nathaniel Brown Palmer, an American sea captain; and Fabian von Bellingshausen, of the Russian Imperial Navy.

Several countries sent expeditions to Antarctica to carry on scientific research. In 1840, an American naval officer named Charles Wilkes led an expedition that charted part of the coast of the continent. From 1839 to 1843, James Clark Ross, a British naval officer, commanded an expedition that sailed into what is now called the Ross Sea. Ross discovered the volcanoes Mount Erebus and Mount Terror, which he named after his ships, *Erebus* and *Terror*. He continued southward until his progress was blocked by a massive barrier of ice now known as the Ross Ice Shelf.

During the late 1890's and early 1900's, Belgium, Britain, Germany, and Sweden sent scientific expeditions to explore the continent. Robert Falcon Scott, a British naval officer, led an expedition from 1901 to 1904 that discovered what is now called Edward VII Peninsula. Scott's expedition used sleds pulled by dogs to travel deep into the interior of the continent.

In 1911, two groups of explorers raced across Antarctica to reach the South Pole. One group was led by Amundsen and the other by Scott. Amundsen reached the pole on Dec. 14, 1911, about five weeks before Scott. Scott and the four other members of his group who reached the pole died on the return trip.

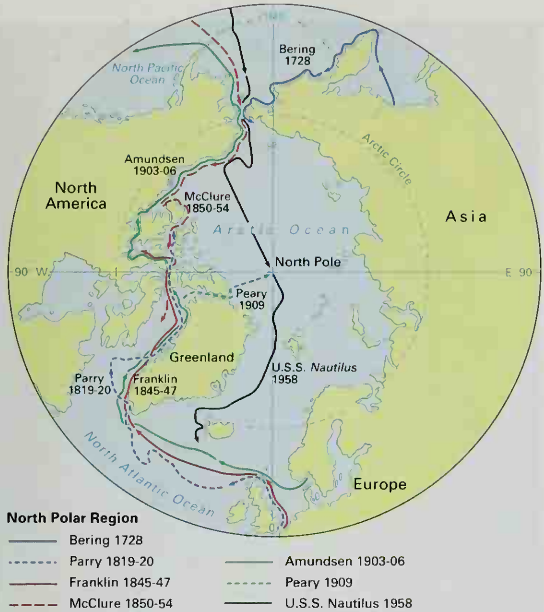
Brown Brothers

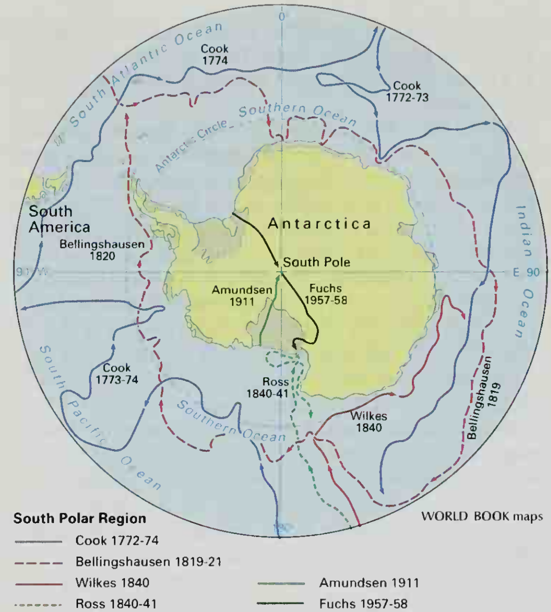
Roald Amundsen of Norway led the first group of explorers to reach the South Pole. They arrived there on Dec. 14, 1911.

During the 1920's, aircraft began to be used to explore Antarctica. George Hubert Wilkins, an Australian explorer, made the first Antarctic airplane flight in 1928. The same year, Byrd went to Antarctica with three airplanes and built a base on the Ross Ice Shelf called Little America. He used the planes to carry on long-range exploration. On Nov. 28 and 29, 1929, he led the first flight over the South Pole. Bernt Balchen, a Norwegian American pilot, flew the plane over the pole.

During the 1950's, many nations built bases on Antarctica from which to conduct scientific research. In 1957 and 1958, an expedition led by Vivian Fuchs *(fyooks)*, a British geologist, accomplished the first overland crossing of Antarctica. The members of the expedition used snow tractors and dog teams to make the crossing. Their journey covered 2,158 miles (3,473 kilometers) and took 99 days.

In 1989 and 1990, Will Steger of the United States led a team of explorers from six nations across Antarctica. The





Exploration of the frigid polar regions began during the 1700's. However, explorers did not reach the North Pole until 1908 or 1909 and did not arrive at the South Pole until 1911.

expedition, which traveled by dog sled and ski, was the first to cross the continent without motorized vehicles.

The new frontiers

Throughout history, the unknown has attracted explorers to the earth's farthest and most isolated places. Today, this same urge continues to draw men and women toward the newest frontiers of exploration: the ocean depths and outer space.

Deep-sea exploration. Early explorers and geographers were curious about the seas and the life forms that lived in them. They often took *soundings* (measurements) of the depth of the oceans. They also tried to determine deep-sea temperatures and used dredges to bring marine life to the surface.

The first expedition devoted entirely to the study of the sea was organized in 1872 by Britain's Royal Navy and the Royal Society of London, a British scientific association. A naval vessel called the *Challenger* was specially equipped for the expedition and placed under the command of Captain George S. Nares. Charles Wyville Thomson, a Scottish naturalist, was put in charge of the civilian scientists. The *Challenger* spent more than three years at sea and traveled nearly 70,000 miles (113,000 kilometers). The expedition made hundreds of soundings, gathered much information about the ocean floor, and discovered many marine organisms.

In the early 1900's, the development of *echo sounders* made it easier to determine the depth of the ocean. These devices were based on the principle that sound waves travel through water at a known rate. Echo sounders enabled navigators to make continuous measurements while a ship was moving and gave a much clearer picture of the ocean floor.

In the mid-1900's, explorers and scientists began to get firsthand views of the underwater world. In 1943, Jacques-Yves Cousteau *(zhahk eev koo STOH),* a French naval officer, and Émile Gagnan *(ay MEEL GAHN yahn),* a French engineer, invented the *aqualung.* This device allowed divers to breathe air from canisters on their backs and to move freely underwater.

In the late 1900's, divers penetrated deep into the ocean with the help of improved suits and breathing apparatus. In 1979, for example, Sylvia A. Earle, an American marine biologist, made a record-breaking dive by descending 1,250 feet (381 meters) to the ocean floor off Hawaii. Earle wore a special kind of diving suit called a *Jim-suit.*

Deep-sea explorers in the 1900's also used piloted submersibles to study the oceans. In 1934, William Beebe *(BEE bee),* an American naturalist, and Otis Barton, an American engineer, descended 3,028 feet (923 meters) into waters off Bermuda in a vehicle called a *bathysphere.*

Auguste Piccard *(oh GOOST pee KAHR),* a Swiss physicist, made a major contribution to ocean exploration during the 1940's. He invented a diving vehicle known as a *bathyscaph,* which could descend farther than any craft of its day. In 1960, Piccard's son Jacques and Donald Walsh of the U.S. Navy used a bathyscaph to dive into the Mariana

© Seth Resnick

Sylvia A. Earle of the United States made a record-breaking ocean dive near Hawaii in 1979.

Trench, a valley in the Pacific Ocean floor that is the lowest known place in the world. They reached the bottom at a point 35,800 feet (10,911 meters) beneath the surface of the water.

By the late 1900's, marine geologist Robert D. Ballard and other scientists had developed new types of exploring equipment, including remotely operated diving vessels and robots, to study the sea. In the late 1970's, Ballard and a team of explorers discovered strange worms and other life forms living near hot water vents on the Pacific Ocean floor. In 1985, Ballard and French oceanographer Jean-Louis Michel led a team of French and American explorers who found the wreckage of the *Titanic,* which had sunk in the North Atlantic in 1912.

For more information on deep-sea exploration, see **Ocean** (Exploring the ocean).

Space exploration. The rockets first used for space exploration were developed for warfare during World War II (1939-1945). For example, Germany developed a rocket-powered missile called the V-2. Some of these missiles were captured by the United States and used to launch exploratory instruments after the war.

After World War II ended, the United States and the Soviet Union engaged in an intense rivalry known as the Cold War. The two nations built increasingly powerful rocket-powered missiles, including ones that could fly across continents.

The space age began on Oct. 4, 1957. That day, the Soviet Union launched Sputnik 1, the first artificial satellite, into orbit around the earth. On Jan. 31, 1958, the United States sent up its first space satellite, Explorer 1.

Most space exploration has been conducted by mechanical and electronic robots. Starting in the late 1950's, spacecraft carrying no crew have been sent to the moon and various planets to gather information that cannot be obtained in any other way. In 1977, the United States launched Voyager 1 and Voyager 2, two identical spacecraft with powerful telescopic cameras. From 1979 to 1981, both craft flew near Jupiter and Saturn. Voyager 2 flew past Uranus in 1986 and Neptune in 1989. Both spacecraft sent back data and photographs that greatly enriched scientists' knowledge of these planets. The United States launched the Hubble Space Telescope in 1990. This orbiting telescope provides sharper pictures of heavenly bodies than other telescopes do.

The first person to travel in space was Yuri Gagarin, a Soviet Air Force officer. On April 12, 1961, he circled the earth one time in a spacecraft called Vostok 1. On Feb. 20, 1962, John H. Glenn, Jr., a United States Marine test pilot, became the first American to orbit the earth. His Friendship 7 spacecraft circled the planet three times. During the rest of the 1960's, the United States conducted a series of programs directed toward landing astronauts on the moon. On July 20, 1969, United States astronauts Neil A. Armstrong and Buzz Aldrin became the first people to set foot on the moon. During the next three years, 10 other United States astronauts landed on the moon.

In 1981, the United States launched its first *space shuttle,* a vehicle that takes off like a rocket and lands like an airplane. The world's first permanent space station, the Soviet Union's Mir, went into orbit in 1986. At first, the United States planned to launch its own space station. But after the breakup of the Soviet Union and the end of the Cold War in 1991, the United States decided to combine its space station program with Russia's. In 1996, for example, Shannon Lucid, an American astronaut and biochemist, was launched into space on a space shuttle and spent more than six months on Mir.

Jeff Hester and Paul Scowen (Arizona State University/NASA)

Images from the Hubble Space Telescope show stars forming from clouds of gas. The orbiting Hubble, launched in 1990, aids in the exploration of one of the final frontiers—space.

The United States, Russia, and other countries plan to assemble an International Space Station by 2006. The first two sections of the station were launched and coupled together in 1998, and crew members occupied the station in 2000. The space station program promises exciting opportunities for further discovery. Helen Delpar

Related articles. For biographies of space explorers, see the *Related articles* listed in the **Astronaut** article. See also:

American explorers

Andrews, Roy Chapman
Ballard, Robert Duane
Bartlett, Robert Abram
Beebe, William
Bennett, Floyd
Bonneville, Benjamin de
Bridger, Jim
Byrd, Richard Evelyn
Clark, William
Colter, John
Cook, Frederick Albert
Earle, Sylvia Alice
Eielson, Carl Ben
Ellsworth, Lincoln
Fairchild, David Grandison
Frémont, John Charles
Gray, Robert
Henson, Matthew Alexander
Lewis, Meriwether
Long, Stephen Harriman
MacMillan, Donald Baxter
Muir, John
Palmer, Nathaniel Brown
Peary, Robert Edwin
Pike, Zebulon Montgomery
Roosevelt, Theodore, Jr.
Smith, Jedediah Strong
Stephens, John Lloyd
Wilkes, Charles

Canadian explorers

Bernier, Joseph Elzéar
Fraser, Simon
Mackenzie, Sir Alexander
McKay, Alexander
Thompson, David

English explorers

Baffin, William
Baker, Sir Samuel White
Burton, Sir Richard Francis
Cook, James
Dampier, William
Davis, John
Drake, Sir Francis
Franklin, Sir John
Frobisher, Sir Martin
Fuchs, Sir Vivian Ernest
Gilbert, Sir Humphrey
Gosnold, Bartholomew
Hearne, Samuel
Henday, Anthony
Hudson, Henry
Kingsley, Mary Henrietta
Parry, Sir William Edward
Puget, Peter
Raleigh, Sir Walter
Ross, Sir James Clark
Scott, Robert Falcon
Vancouver, George
Wallace, Alfred Russel

French explorers

Bienville, Sieur de
Brulé, Étienne
Cartier, Jacques
Champlain, Samuel de
Cousteau, Jacques-Yves
Groselliers, Sieur des
Iberville, Sieur d'
Jolliet, Louis
La Salle, Sieur de
La Vérendrye, Sieur de
Le Sueur, Pierre-Charles
Marquette, Jacques
Monts, Sieur de
Nicolet, Jean
Radisson, Pierre Esprit
Roberval, Sieur de
Tonty, Henri de

Italian explorers

Cabot
Columbus, Christopher
Kino, Eusebio Francisco
Polo, Marco
Verrazzano, Giovanni da
Vespucci, Amerigo

Norwegian explorers

Amundsen, Roald
Eric the Red
Ericson, Leif
Nansen, Fridtjof

Portuguese explorers

Cabral, Pedro Álvares
Da Gama, Vasco
Dias, Bartolomeu
Henry the Navigator
Magellan, Ferdinand

Spanish explorers

Ayllón, Lucas Vásquez de
Balboa, Vasco Núñez de
Cabeza de Vaca, Álvar Núñez
Cabrillo, Juan Rodríguez
Coronado, Francisco Vásquez de
Cortés, Hernando
De Soto, Hernando
Jiménez de Quesada, Gonzalo
Menéndez de Avilés, Pedro
Narváez, Pánfilo de
Oñate, Juan de
Orellana, Francisco de
Pizarro, Francisco
Ponce de León, Juan
Torres, Luis Vaez de

Other explorers

Alexander the Great
Barents, Willem
Bering, Vitus
Emin Pasha
Estevanico
Hennepin, Louis
Hillary, Sir Edmund Percival
Ibn Battuta
McClure, Sir Robert John Le Mesurier
Nordenskjöld, Nils Adolf Erik
Park, Mungo
Piccard
Pytheas
Shackleton, Sir Ernest Henry
Stanley and Livingstone
Tasman, Abel Janszoon
Wilkins, Sir Hubert

Other related articles

Africa (History)
Antarctica (Exploration)
Arctic (Exploration)
Astronaut
Australia (History)
Balloon (History)
Caravel
Cíbola, Seven Cities of
Colonialism
Deep sea (Deep-sea exploration)
El Dorado
Fur trade
Geography
Latin America (History)
Lewis and Clark expedition
Map (History)
Northwest Passage
Ocean (Exploring the ocean)
Ptolemy
Ship (History)
Space exploration
Trade route
Vikings
Vinland

Outline

I. The first explorers

II. Ancient exploration
A. The Phoenicians
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IV. The great age of European exploration
A. Reaching the tip of Africa
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E. Magellan's globe-circling expedition
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E. Exploring Australia's interior
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VI. The new frontiers
A. Deep-sea exploration
B. Space exploration

Questions

Why did Europeans become eager to find a direct sea route to Asia during the 1400's?
What technological developments made long voyages possible by 1500?
Who was the most celebrated Muslim explorer? Where did he travel?
What are some of the effects the arrival of Europeans had on American Indians and Australian Aborigines?
Who was probably the first woman to sail around the world?
What obstacles made exploration of the interior of Africa difficult?
Who were the leaders of the first European party to cross Australia from south to north?
What are echo sounders? How did they help deep-sea exploration?
Who was the first European to see the eastern shore of the Pacific Ocean?
How did the Cold War affect the coming of the space age?

Additional resources

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Explosive is a material that produces a rapid, violent reaction when acted upon by heat or a strong blow. During this reaction, explosives give off large amounts of gases at high pressure. The enormous power released during an explosion gives explosives many commercial and military uses. Explosives enable construction workers to clear land of tree stumps and boulders to begin building roads or structures. They are used in *excavating* (digging) mines and to loosen the flow of oil deep beneath rock in oil wells. They blast tunnels through mountains. In war, explosives are used to damage cities, destroy ships and airplanes, and kill enemy troops.

Explosives may be solids, liquids, or gases. However, all explosives consist of a fuel and an *oxidizer*—a substance that supplies the oxygen needed to make the fuel burn. When the most powerful explosives *detonate* (explode), a chemical reaction takes place in less than a millionth of a second. Liquids and solids change to hot gases that expand with a great blast of heat and pressure. The higher the pressure, the more powerful the explosion will be.

Certain types of explosives detonate in a nuclear reaction rather than a chemical reaction. For a detailed discussion of nuclear explosions, see **Nuclear weapon**. This article discusses four chief types of chemical explosives—primary explosives, high explosives, blasting agents, and low explosives.

Primary explosives must be handled in small quantities. They are extremely sensitive to heat, and even a spark of static electricity can cause them to explode. Common primary explosives include lead azide, lead styphnate, and mercury fulminate. They are chiefly used in devices called *detonators* to set off other explosives (see **Detonator**).

High explosives detonate with greater power than primary explosives but are less sensitive. Common types of high explosives include nitroglycerin; RDX; TNT; PETN; and *pentolite,* a combination of TNT and PETN. Most high explosives are used commercially for blasting and excavating, but they also are used by the military in bombs, artillery shells, and grenades.

High explosives are sometimes mixed with substances called *plasticizers* to produce *plastic explosives.* Plasticizers, such as oil and wax, make it easy to mold the explosives into various shapes. Plastic explosives have been used by terrorists in bombs and by armed forces in land mines.

Blasting agents are the safest and least expensive explosives used in industry. They are often used to shatter and heave rock in mining and excavating operations. Common blasting agents include dynamite and mixtures of ammonium nitrate and fuel oil.

Low explosives *deflagrate* (burn rapidly) rather than detonate. The most common type of low explosive is gunpowder. It serves as a *propellant* to shoot ammunition from guns and other weapons. Fireworks are also low explosives. James E. Kennedy

Related articles in *World Book* include:

Ammunition
Bomb
Cordite
Depth charge
DuPont Company
Dynamite
Fireworks
Fuse
Guncotton
Gunpowder
Maxim, Hudson
Mine warfare
Nitroglycerin
PETN
Plastic explosive
RDX
TNT

Exponent. See **Algebra** (Terms used in algebra).

Export-Import Bank of the United States, also called *Eximbank,* is an independent agency of the United States government. The bank provides financial services that promote the export of U.S. goods and services and thus enable U.S. exporters to compete with foreign companies on the world market. In some cases, Eximbank lends money to buyers of U.S. exports. The bank also guarantees the repayment of loans made by commercial banks to finance export activities and offers insurance on the credit that exporters extend to foreign purchasers.

Eximbank was established in 1934 and has authorized billions of dollars in export assistance. A five-member board of directors manages the bank, which is in Washington, D.C. The directors are appointed by the president, subject to approval by the Senate.

Critically reviewed by the Export-Import Bank of the United States

Exports and imports are the articles shipped from and into a country. The term *export* comes from Latin words meaning *to carry out. Import* comes from Latin words that mean *to carry in.*

The pattern of exports and imports

Reasons for exports and imports. A country exports goods under the following conditions: (1) if the country is one of the world's few suppliers of a certain product; (2) if the country produces the merchandise at a lower cost than other countries; or (3) if the country's goods are in demand because of their outstanding quality.

Some imports consist of goods that are not produced domestically. For example, the climate of the mainland United States is not suitable for growing coffee. For this reason, the United States imports coffee beans from countries in Latin America and Africa. Most imports purchased by large countries, however, consist of goods that are similar to those goods produced locally but are different in price or quality. For example, the United States imports inexpensive Hyundai automobiles from South Korea and luxury Mercedes-Benz cars from Germany, even though other automobiles are produced in the United States.

Reasons for change. A nation's pattern of exports and imports tends to change over the years. This change may be due to technological developments. For example, the discovery of synthetic substitutes for such natural products as silk and rubber reduced the need to import these natural products. The development of new products often creates new trade patterns because people in all countries want these conveniences no matter what country produces them. Foreign investment, such as building factories in other countries, may enable countries to export products that they previously imported.

Government policies may affect the exports and imports of a country. For example, lowering tariffs allows

greater imports of products from abroad. In the same way, lowering of trade barriers by other countries opens markets for exports.

Attitudes toward exports and imports

Popular opinion within a country usually favors national exports over imports. Many people, particularly local producers and workers, believe exports create jobs. They resent imported products—especially ones that compete with similar products made in their own country. Many people think that imports lower living standards by decreasing job opportunities at home and by causing money to be spent outside the country.

Economists, in contrast with the public, believe that exports and imports are equally important. To the economist, it is more efficient and economical for a nation to import from abroad goods that are either cheaper or of better quality. The nation can then use its resources, work force, and equipment to specialize in goods that it produces better than other countries—and to export those goods. Further, most economists believe that imports act as a spur for domestic manufacturers to improve their products and cut their costs.

Government policies

Export promotion. Some governments artificially promote their nation's exports by giving exporters a cash grant called a *subsidy.* For example, the European Union, an economic and political association of European countries, guarantees its exporting member nations a minimum price for selling wheat. When the world market price for wheat falls below that price, the union pays the member a subsidy to cover the difference between the lower market price and the higher guaranteed price.

Another artificial arrangement to promote exports consists of special tax incentives. A government may exempt export industries from corporate taxes that other businesses must pay. A government may also increase exports by reducing the value of its currency in relation to other countries' currencies. Such a reduction makes the exporting country's goods cheaper for importers—and consumers—in other countries.

Import restrictions. A common restrictive device is the import *tariff,* a tax on imports. The United States limits imports chiefly by imposing tariffs. Many other countries restrict trade with an *import quota,* which sets an absolute limit on imports. Efficient producers may be able to lower their prices enough to absorb a tariff and still export their goods. But no degree of efficiency can help producers when they face a rigid limit on the number of items a country may import.

Developing countries, such as Brazil and India, often use regulations called *foreign exchange controls* to restrict imports. Such controls limit the payments importers may make to foreign suppliers for certain goods.

Unexpected costs and delays at the customs office are still another type of import restriction. For example, a customs officer may place an arbitrarily high value on certain imports. When tariff duties are based on such valuations, an arbitrarily high valuation imposes unexpected costs on importers. Strict health or safety requirements may also present a barrier to trade.

Government policy toward imports varies with a nation's degree of industrial development. The economically most advanced nations, such as the United States, Japan, and the nations of Western Europe, tend to favor lowering import restrictions. They want to widen world markets for their exports and to promote economic growth and productive efficiency. Their advanced industries rely on product research and skilled management for competitiveness in world markets. Some of the more advanced developing nations, such as Chile, Mexico, South Korea, Thailand, and some Eastern European nations, reduced import barriers in the 1980's.

Many of the less developed countries in Africa, Asia, and Latin America still rely on import restrictions. They feel that such protection is necessary for the growth of their infant industries. They point to the importance of restrictions in the past industrial growth of economically advanced nations. Gary Hufbauer

Related articles. See the sections on *Trade* in various country articles. See also the following articles:

Balance of payments	International trade
Free trade	Reciprocal trade agreement
General Agreement on Tariffs and Trade	Tariff
	Trade

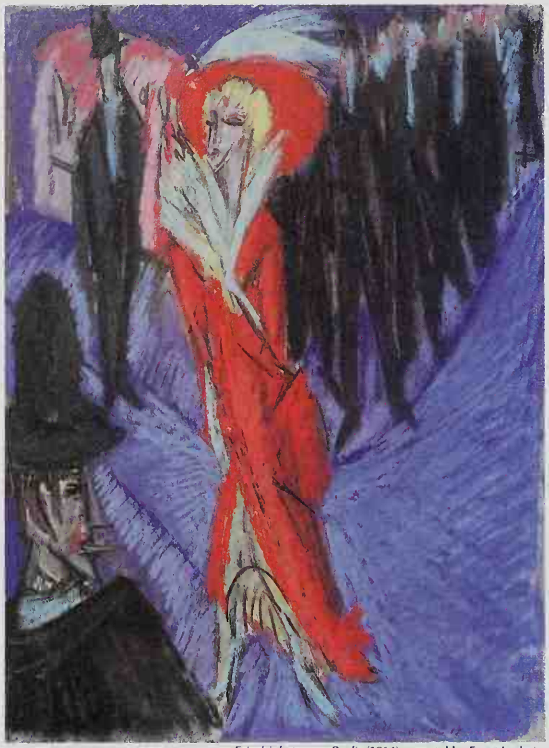
Exposition. See Fair.

Expressionism was an art movement that flourished in the early 1900's. Art critics invented the term to describe a style of painting which developed from, and in reaction to, the kind of painting called *impressionism.* Impressionist painters were mainly concerned with how the surface of objects appeared to the eye at a particular moment. Expressionists tried to give form to their strong inner feelings. They tried to portray life as modified and distorted by their personal interpretation of reality. To them, truth or beauty was in the mind and the soul, not in the eye. See Impressionism; Postimpressionism.

The emotional range of expressionist art encompasses both intense joy and deep despair. Expressionist imagery accordingly may be either bright and ecstatic or dark and painful. Vincent van Gogh's *The Starry Night* is a good example of a joyful expressionist work. Van Gogh deliberately distorted the size and appearance of the heavenly bodies, using vivid colors and energetic, swirling brushstrokes. The painting is an expression of van Gogh's highly personal experience of the star-filled night sky, rather than a simple record of how such a sky appears to the observant eye. The rapturous excitement of the painting is primarily the product of van Gogh's mind and emotions. Edvard Munch's painting *The Scream,* with its image of intense anxiety and alienation, represents the darker side of expressionism. *The Scream* is reproduced in the Munch, Edvard article.

Expressionist painting. Elements of expressionism can be traced at least as far back as the Spanish painter El Greco in the early 1600's. The expressionist movement itself began in the late 1800's. Its leading figures were van Gogh of the Netherlands, Munch of Norway, Paul Gauguin of France, and James Ensor of Belgium.

The first group organized to promote the expressionist idea was called *Die Brücke* (The Bridge). It flourished in Germany from 1905 to 1913. Emil Nolde and Ernst Ludwig Kirchner were two of its best-known members. A later and more influential group was called *Der Blaue Reiter* (The Blue Rider). It included Wassily Kandinsky of Russia, Paul Klee of Switzerland, and Franz Marc of Ger-



Friedrichstrasse, Berlin (1914), a pastel by Ernst Ludwig Kirchner; Staatsgalerie, Stuttgart, Germany

An expressionist painting shows how artists use distortion and bright colors to create an intense emotional impact.

many. Through its paintings and writings, *Der Blaue Reiter* influenced the work of many artists, especially Georges Rouault of France, Marc Chagall of Russia, Max Beckmann and George Grosz of Germany, and Oskar Kokoschka of Austria.

Paintings by Gauguin, Kandinsky, and Kokoschka appear in the *Expressionism* section of the **Painting** article.

Expressionist writing, especially drama, flourished in the early 1900's. Expressionist playwrights were influenced by the dramatic forms and stage techniques made popular by August Strindberg of Sweden. Expressionist drama first developed as a movement in Germany. Its influence spread, reaching its height after World War I in the plays of Ernst Toller, Frank Wedekind, Georg Kaiser, and Josef and Karel Čapek. In the United States, the plays of Elmer Rice, Eugene O'Neill, and others show the influence of expressionism.

Characters in expressionist drama tend to be one-sided, standing for single ideas and attitudes. They are placed in situations in which the objects of the outer world are distorted to reveal the tortured minds of the characters or the dramatist. Playwrights achieved these effects with symbolic settings, bizarre lighting, and non-realistic acting. See **Drama** (Modern drama: Ibsen to World War II; picture).

Expressionist drama often showed the influence of modern psychology by reflecting the inner frustrations of the dramatist. Many plays showed characters in the grip of fear and other violent emotions. Some playwrights, influenced by the philosophy of Karl Marx, criticized the evils they saw in society.

The influence of expressionism can also be seen in the fiction of the German-Czech author Franz Kafka and in some German poetry of the early 1900's. Although expressionism is no longer a specific movement, its aims and methods may still be found in much contemporary drama and art. David Cateforis

Related articles in *World Book* include:

Abstract expressionism
Barlach, Ernst Heinrich
Beckmann, Max
Čapek, Karel
Ensor, James
Gauguin, Paul
Greco, El
Grosz, George
Kafka, Franz
Kaiser, Georg
Kandinsky, Wassily
Klee, Paul
Kokoschka, Oskar
Motion picture (Filmmaking in Europe)
O'Neill, Eugene G.
Opera (The search for new forms)
Rice, Elmer
Schiele, Egon
Strindberg, August
Van Gogh, Vincent

Extension programs are educational services that colleges offer to people who cannot attend school full-time or who live far from a campus. Extension classes are held during the day and evening throughout the week, including weekends. They may take place on a college or university campus or in off-campus buildings, such as churches, public elementary and high schools, and factories and office buildings. Many extension programs also reach students through correspondence courses, radio, and closed-circuit television.

Extension programs offer a variety of courses to meet the needs of many people. Numerous business and professional people attend extension classes to keep up with developments in their fields. Some people take extension courses to earn credit toward a college degree. Others attend extension classes for enjoyment or to learn a skill. For example, extension programs offer such courses as automobile repair, painting, and typing.

Many of the differences between extension courses and other college courses have begun to disappear. Formerly, students did not receive the same academic credit for extension classes as they did for regular course work. Today, however, many of the credits earned in extension courses may be applied toward a college degree. Many colleges and universities also offer evening and weekend classes as part of their regular program, rather than as an extension program.

Cambridge University in England established one of the first university extension programs in 1873. William Rainey Harper, the first president of the University of Chicago, founded an extension division at that university, which opened in 1892. Many other universities in the United States soon began extension programs.

The term *extension service* refers to a nationwide program of agricultural education sponsored jointly by the United States Department of Agriculture and by state and county governments. The program uses newsletters, television, personal demonstrations, and similar means to keep farmers up to date on new equipment, techniques, varieties of plants, and other developments in agriculture. Leonard Nadler

See also **Adult education; Correspondence school; Distance learning.**

Extinct animal. A species of animal becomes extinct when every one of its kind has died. Extinction is a process that has occurred since life appeared on earth.

Why animals become extinct is not always clear. Many scientists believe that a balance exists in nature, so that the establishment of a new species results in the loss or extinction of an existing species. Scientists have found that species tend to live for a certain period of time and then they disappear. For example, species of birds and mammals tend to live about 1 million years. Species of clams and snails may live 10 to 12 million years. Most species of animals living today can be traced back as fossils only a few million years.

Types of extinction. Scientists distinguish several kinds of extinction. Some species of animals simply become extinct and leave no descendants. For example, a group of common early animals were flat shellfish called *trilobites.* But they died out entirely by about 248 million years ago.

Other species *evolve* (change gradually) into extinction over many generations, but leave descendant species that may differ only slightly from the parent species. For example, the earliest horse, called *Eohippus* or *Hyracotherium,* stood only 10 to 20 inches (25 to 50 centimeters) high at the shoulder and had four toes on each of its front feet. Through fossils, scientists have traced a chain of about 30 species over 60 million years from *Eohippus* to the modern horse. Each species has slightly different features, such as a bigger body and fewer toes, from its extinct ancestors.

In other cases, great numbers of unrelated species of animals have died out at certain times. Such episodes of *mass extinction* have led to the rise of new animal groups that dominated the environment of the earth for millions of years afterward. Thus, the disappearance of dinosaurs during a mass extinction 65 million years ago allowed mammals to gain dominance.

Causes of extinction. Most extinct animals died out because of changes in their environment, such as the cooling of the climate, the loss of their food source, or the destruction of their habitat. However, scientists often disagree about the specific cause of an extinction. For example, they offer many theories about why dinosaurs disappeared, including the collision of an asteroid with the earth and the inability of dinosaurs to compete successfully with mammals for food (see **Dinosaur** [Why dinosaurs died out]).

Human beings have caused many animals to become extinct. Such activities as farming, hunting, and logging, or mere settlement by humans, contribute to extinctions. Today, the growth of urban areas and the pollution of the environment with pesticides and industrial wastes pose serious threats to many species.

Prehistoric extinctions. Several great mass extinctions occurred during prehistoric times. The largest mass extinction was about 248 million years ago, at the end of the Permian Period, when possibly as much as 96 percent of all species disappeared. Two other mass extinctions took place during the Mesozoic Era—one around 205 million years ago, the other around 138 million years ago. Many species of amphibians and reptiles died out, and dinosaurs became common. Probably the best-known mass extinction occurred about 65 million years ago, when the dinosaurs and many species of marine life died out.

Extinctions in modern times have occurred at such a rapid rate that some scientists believe another mass extinction may be taking place. Human activities have caused most of these extinctions. During the last 200 years, more than 50 species of birds, over 75 species of mammals, and perhaps hundreds of other species of animals have become extinct. The dodo, great auk, Labrador duck, moa, and passenger pigeon are among the birds that have disappeared. Mammals that are now extinct include Steller's sea cow and a form of zebra called a quagga. Several species, including Przewalski's horse and the European bison, have died out in the wild but have been preserved in captivity or on reserves.

Peter Dodson

See also **Bird** (Extinct birds); **Earth** (table); **Endangered species; Fossil; Prehistoric animal.**

Extortion is the attempt to obtain money or property by threatening to physically harm a person, injure a person's property or reputation, or accuse a person of a crime. The payment, or bribe, is often called *hush money.* The meaning of the term *extortion* was originally limited to the collection of illegal fees by a public official. Today, such a crime is called *bribery.* If a private person does it, it is called *blackmail.* Both crimes are considered kinds of extortion, and they are punishable by a prison term or fine, or both. See also **Blackmail; Bribery; Racketeering.** Charles F. Wellford

Extract is a concentrated preparation of certain substances obtained from plants, herbs, flowers, or animal tissues. Extracts are widely used as flavorings in cooking. Popular flavoring extracts include cherry, lemon, maple, orange, vanilla, and meat extracts. Extracts are also used in cosmetics, medicines, and perfumes.

Several methods are used to prepare extracts. For example, orange extract is obtained by pressing or squeezing orange rinds. Vanilla extract is made by percolating crushed vanilla beans through an alcohol-water mixture. Meat extracts are produced by boiling meat in liquid and then reducing the cooking liquid to a paste by evaporation.

Many drugs are extracted from plants. For example, morphine, a painkiller, comes from the opium poppy. Cosmetic extracts, called *essences,* are used in perfume, soap, toothpaste, and shampoo. They include ambergris, benzoin, castor, musk, and balsam.

Jane Ann Raymond Bowers

See also **Meat extract; Perfume.**

Extradition, *EHKS truh DIHSH uhn,* is the handing over by one state or country to another of people accused of crimes. The word *extradition* comes from two Latin words meaning *out of* and *delivering up.*

In early times, people who committed crimes were able to escape punishment by fleeing to another country. But in the late 1700's, nations began to arrange extradition treaties among themselves. Such treaties provide that proper authorities must return people accused of certain crimes to the country in which they committed the crimes at the demand of that country.

Ordinarily, people cannot be extradited for political crimes. The United States holds extradition treaties with more than 80 countries. The United States Constitution provides that any state shall, on demand of another state, extradite a person accused of a crime.

Paul C. Giannelli

Extrasensory perception, usually abbreviated ESP, describes a way of communicating or of being aware of

something without using the known senses. An awareness of another person's thoughts without the use of sight, hearing, taste, touch, or smell would be an example of ESP. The study of extrasensory perception is part of the field of psychology called *parapsychology.* The evidence for the existence of ESP is highly debatable. Most scientists believe ESP is something whose existence is yet to be proven.

What parapsychologists study. Extrasensory perception is commonly divided into three kinds of phenomena—(1) telepathy, (2) clairvoyance, and (3) precognition. *Telepathy* is the sensing of the thoughts or feelings of one person by another in some unknown way. *Clairvoyance* is an awareness of objects, events, or people without the use of the known senses. *Precognition* is knowledge of a future event by means of telepathy or clairvoyance. Some parapsychologists also study phenomena related to ESP, such as *psychokinesis.* Psychokinesis is the mental control of physical objects, such as influencing the fall of dice by concentration.

ESP research. Many classic ESP experiments, developed and used mainly between 1930 and 1960, involved card guessing. A deck of 25 special *ESP cards* (also called *Zener cards,* after the American psychologist Karl E. Zener) was often used. Each ESP card has one of five different symbols on it, such as a circle or cross. In a simple test of telepathy, a person called the *sender* would look at or think of a given card and concentrate on its symbol. A second person, called the *receiver,* was usually in another room and would attempt to name the symbol that the sender was thinking of. In an experiment on clairvoyance, cards would be taken from the deck one at a time, and the receiver would try to name the symbols on the cards. In this case, the person taking the cards would not look at the symbol.

In these experiments, one would expect 5 correct answers out of 25 calls just by chance if the receiver were only guessing. Most parapsychologists would consider a person who consistently averaged 7, 8, or more correct calls after many tests to have some ESP ability.

The use of computers and electronic random-number devices has almost entirely replaced the use of cards in ESP experiments. Some such research has produced controversial claims that subjects are able to influence or predict the decay of radioactive substances. This kind of influence or prediction is impossible in terms of modern scientific understanding.

Possible misunderstandings. In spite of the lack of widely accepted evidence about ESP, many people believe that it is valid because of personal experiences that seem to be unexplainable otherwise. But most of these experiences can be explained by psychological processes that most people are not aware of. People often do not know how events around them set off their thoughts. Two people who know each other well may both experience a similar chain of thoughts when exposed to a common stimulus. For example, a husband and wife may be reading together and not paying much attention to music on a radio. Then certain music triggers in each of them the memory of a person they met several years ago but have not encountered since. Just as one of them is about to bring up the person's name, the other one mentions it. These similar thoughts may seem to be an instance of extrasensory perception. But neither person is likely to realize that both of their thoughts were actually set off by the music.

Debate about ESP. One of the most noted American ESP researchers was J. B. Rhine, who headed the Parapsychology Laboratory at Duke University for many years. Rhine conducted a number of card-guessing experiments to test clairvoyance, precognition, and telepathy. Some researchers claim that evidence based on the work of Rhine and other investigators has established beyond question the existence of ESP.

But other researchers believe that the evidence is questionable. In the early days of ESP research, when fairly crude experiments were used, some people put on rather remarkable telepathic or clairvoyant performances. Today, however, when experiments are more carefully controlled, similar performances are rare. In science, the trend should generally be in the opposite direction. That is, if the phenomena under investigation are real, improved experiments should produce more significant and well-defined results.

Another reason for skepticism is that after more than a hundred years of research, no scientist has been able to produce a repeatable demonstration of ESP that can be performed before a group of neutral scientists. Some parapsychologists have responded that the fault may lie with the experimenter. They suggest that skeptical researchers may have attitudes that prevent them from producing or witnessing ESP.

Continued belief in ESP is likely to endure regardless of the weakness of the evidence. Many people strongly believe that some elements of human existence are not subject to physical laws or methods. ESP, if it could be proven to exist, would help to explain these elements. ESP might also give insights into the possibility of life after death. James E. Alcock

See also **Clairvoyance; Mind reading; Parapsychology; Psychical research; Telepathy.**

Extraterrestrial intelligence, *EHKS truh tuh REHS tree uhl,* is intelligent life that developed somewhere other than the earth. No life has been discovered on any planet other than the earth. However, many scientists have concluded that intelligent life may exist on planets orbiting some of the hundreds of billions of stars in our galaxy, the Milky Way. These scientists base their conclusion on research in such fields as astronomy, biology, planetary science, and *paleontology* (the study of prehistoric life through fossils). The effort to find evidence that there is extraterrestrial intelligence is often called SETI, which stands for *S*earch for *E*xtra*t*errestrial *I*ntelligence.

SETI researchers believe that the best way to discover other intelligent life in the galaxy is to look for evidence of technology developed by that life. In the belief that intelligent beings on other worlds would eventually develop radio technology, researchers have used large radio telescopes to search the sky. In 1960, the first SETI experiment unsuccessfully examined two stars at a single radio frequency. After several dozen additional searches, the National Aeronautics and Space Administration (NASA) in 1992 began a two-part project known as the High Resolution Microwave Survey. Researchers searched for weak *microwave* (short radio wave) signals originating near specific stars that are similar to the sun. They also started to scan the entire sky for strong micro-

wave signals. In 1993, the United States Congress, in a budget-cutting measure, instructed NASA to end the project. SETI research continues in the United States under private support.

In 1998, astronomers began to search for pulses of laser light. They reasoned that intelligent beings on a planet orbiting a distant star might have developed powerful lasers. The beings might have sent brief pulses of laser light into space as a signal to observers on other planets. They would have used pulses so that the observers could distinguish the laser light from the bright, steady light coming from their star. Astronomers on the earth would be able to distinguish powerful pulses that lasted for a few billionths of a second. Michael J. Klein

See also **SETI Institute; Unidentified flying object.**

Extraterritoriality, *EHKS truh TEHR uh tawr ee AL uh tee,* is a legal term for the privilege granted to ambassadors, ministers, and other diplomatic agents living in foreign countries. It allows them to remain under the authority of the laws of their own land. They cannot be arrested for breaking laws of countries to which they are sent. If they do break local laws, their governments may be asked to recall them. International conventions and treaties govern the treatment of diplomatic agents and the embassies, legations, and consulates in foreign countries. See also **Diplomacy.** Robert J. Pranger

Extreme unction. See **Anointing of the sick.**

Extrovert, when used nontechnically, means a sociable person who makes friends easily. In psychiatry, the word has a somewhat different meaning. The Swiss psychiatrist Carl G. Jung defined *extroversion* as turning the interests and energies of the mind toward events, people, and things of the outer world. As a result, extroverts are more interested in what is going on around them than in their own thoughts and feelings. In normal people, extroversion is counterbalanced by introversion, and a wholesome balance is maintained between the two tendencies (see **Introvert**). Paula J. Clayton

Extrusion is the process of shaping a piece of solid material, such as steel, by forcing it through an opening. The opening is part of a die and has the same diameter as the finished object. Extrusion produces bars, tubes, and other shapes. This article discusses metal extrusion, but the process is similar for many other materials.

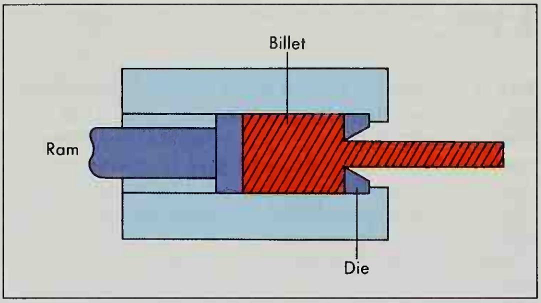
There are three basic extrusion processes: (1) *direct* or *forward,* (2) *indirect* or *reverse,* and (3) *hydrostatic.*

The direct process is the most widely used method of extrusion. In this process, a *ram* (plunger) in one end of a cylinder pushes against a *billet* (short piece of metal). The ram forces the metal through a die opening at the other end of the cylinder. Such great force is used that the metal flows out like toothpaste out of a tube.

The indirect process uses a die and a hollow ram. A billet is pushed against the closed end of a cylinder, forcing the metal out of the cylinder through the die opening and the ram.

The hydrostatic process resembles the direct method, except that fluid, such as castor oil, surrounds the billet. The ram pushes on the fluid, and the fluid pressure forces the metal through the die opening.

Most extrusion processes shape metal that has been heated. Heat increases a metal's ability to be shaped. The temperature of billets may range from 400 °F (204 °C) to more than 4000 °F (2204 °C). The billet and the die usually are coated with a lubricant, such as graphite or melted glass, to help the metal flow smoothly.



WORLD BOOK diagram by Arthur Grebetz

In extrusion, a solid material such as metal is shaped by forcing it through the opening in a die. The ram at one end of a cylinder pushes against a short piece of metal called a *billet.* The billet flows out of the other end of the cylinder.

Extrusion processes that shape metal at room temperature are called *cold* extrusions. There are two such methods—*Hooker* and *impact.* The Hooker method is a direct process. Impact extrusion is indirect. More pressure is needed to shape cold metal than hot metal, but cold extrusion products have greater strength and a higher quality surface finish. Melvin Bernstein

See also **Plastics** (Extrusion); **Rubber** (Shaping).

Exxon Mobil Corporation is the largest petroleum company in the world. It was formed in 1999 when the two largest oil companies in the United States, the Exxon and Mobil corporations, merged. The company is also known as ExxonMobil.

Both Exxon and Mobil began as part of the Standard Oil Trust established by John D. Rockefeller in 1882. In 1911, an antitrust ruling by the Supreme Court of the United States forced the trust to dissolve. The trust was broken up into 34 companies, including the Standard Oil Company of New Jersey and the Standard Oil Company of New York. The New Jersey company changed its name to Exxon Corporation in 1972. The Standard Oil Company of New York became Mobil Oil Corporation in 1966. In 1976, Mobil Oil became a subsidiary of a newly formed Mobil Corporation.

ExxonMobil's principal activities include every phase of the oil and natural gas industry. It owns about 17,000 oil wells and natural gas wells and about 45 refineries. It owns or shares ownership in about 40,000 miles (64,000 kilometers) of pipeline and operates one of the world's largest tanker fleets. More than 40,000 service stations worldwide sell the company's products. ExxonMobil also takes part in the research and development of such energy sources as coal and solar power. In addition, the company manufactures *petrochemicals* (chemicals made from petroleum or natural gas) and has mining interests. The company's headquarters are in Irving, Texas.

Before the merger, Exxon was involved in the largest oil spill in U.S. history. In March 1989, the tanker *Exxon Valdez* struck a reef off southeastern Alaska, spilling nearly 11 million gallons (42 million liters) of crude oil. Exxon paid over $3 billion for cleanup, compensation, and environmental restoration. See **Alaska** (Recent developments). Critically reviewed by Exxon Mobil Corporation

Eyck, Jan Van. See **Van Eyck, Jan.**

Eye

Eye is the organ of sight. It is our most important organ for finding out about the world around us. We use our eyes in almost everything we do—reading, working, watching movies and television, playing games, and countless other activities. Sight is our most precious sense, and many people fear blindness more than any other disability.

The human eyeball measures only about 1 inch (25 millimeters) in diameter. Yet the eye can see objects as far away as a star and as tiny as a grain of sand. The eye can quickly adjust its focus between a distant point and a near one. It can be accurately directed toward an object even while the head is moving.

The eye does not actually see objects. Instead, it sees the light they reflect or give off. The eye can see in bright light and in dim light, but it cannot see in no light at all. Light rays enter the eye through transparent tissues. The eye changes the rays into electrical signals. The signals are then sent to the brain, which interprets them as visual images.

This article deals mainly with the human eye. It discusses the parts of the eye, how we see, defects and diseases of the eye, and care of the eye. The last section of the article describes some of the differences in the eyes of various kinds of animals.

Parts of the eye

Each eyeball is set in a protective cone-shaped cavity in the skull. This cavity is called the *orbit* or *socket.* Its ridges form the brow and the cheekbone. Fatty tissue inside the orbit nearly surrounds the eyeball and cushions it against blows. The soft tissue also enables the eye to turn easily in the orbit. Six muscles move the eyeball in much the same way that strings move the parts of a puppet.

The outer parts of the eye include the *eyelids,* the *conjunctiva,* the *lacrimal glands,* and the *lacrimal sac.* Three layers of tissue form the wall of the eyeball: (1) the sclera and the cornea, (2) the uveal tract, and (3) the retina. Within the wall is a clear, jellylike substance called the *vitreous humor.* This substance occupies about 80 percent of the eyeball. It helps maintain the shape of the eye and the pressure within the eyeball.

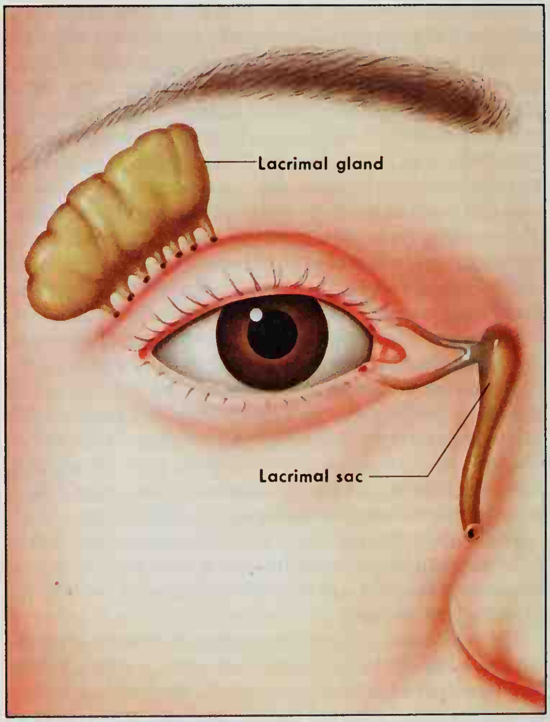
The outer parts. The front of the eyeball is protected by the eyelids. Eyelashes on the lids screen out some of the dust and other particles that might otherwise enter the eye. Any sudden movement in front of the eye—or anything that touches the eyelashes—causes the lids to blink in a protective reflex action.

The conjunctiva is a membrane that lines the inside of the eyelids and extends over the front of the white part of the eye. It produces *mucus,* a clear, slimy fluid that lubricates the eyeball. The conjunctiva also produces some tears, which help keep the eye clean. However, most tears are made by the lacrimal glands. A lacrimal gland lies at the upper outer corner of each orbit. Every time a person blinks, the eyelids spread a smooth layer of mucus and tears over the eye. These fluids then flow into tiny canals in the lids. The canals lead to the lacrimal sac, a pouch at the lower inner corner of each orbit. From the lacrimal sac, the mucus and tears drain through a passage into the nose. After crying, a person may have to blow the nose to clear this drainage system of the excess amount of tears.

The sclera and the cornea consist of tough tissues that make up the outer layer of the eyeball and give it strength. The sclera covers about five-sixths of the eyeball, and the cornea about one-sixth. The sclera is the white part of the eye. It has the strength and feel of soft leather. Although the sclera appears to have many blood vessels on its surface, most of these vessels are part of the conjunctiva. The cornea has no blood vessels at all and has relatively little moisture. As a result, it is transparent. The cornea lies in front of the colored part of the eye and resembles the crystal of a wrist watch. The cornea enables light rays to enter the eyeball.

The uveal tract is the middle layer of the wall of the eyeball. It has three parts. They are, from front to back: (1) the iris, (2) the ciliary body, and (3) the choroid.

The iris is the colored disk behind the cornea. The color of the iris comes from a brownish-black substance called *melanin.* The more melanin there is and the closer it is to the surface of the tissue, the darker the color of the iris. For example, there is more melanin in brown eyes—and the melanin is closer to the surface—than in



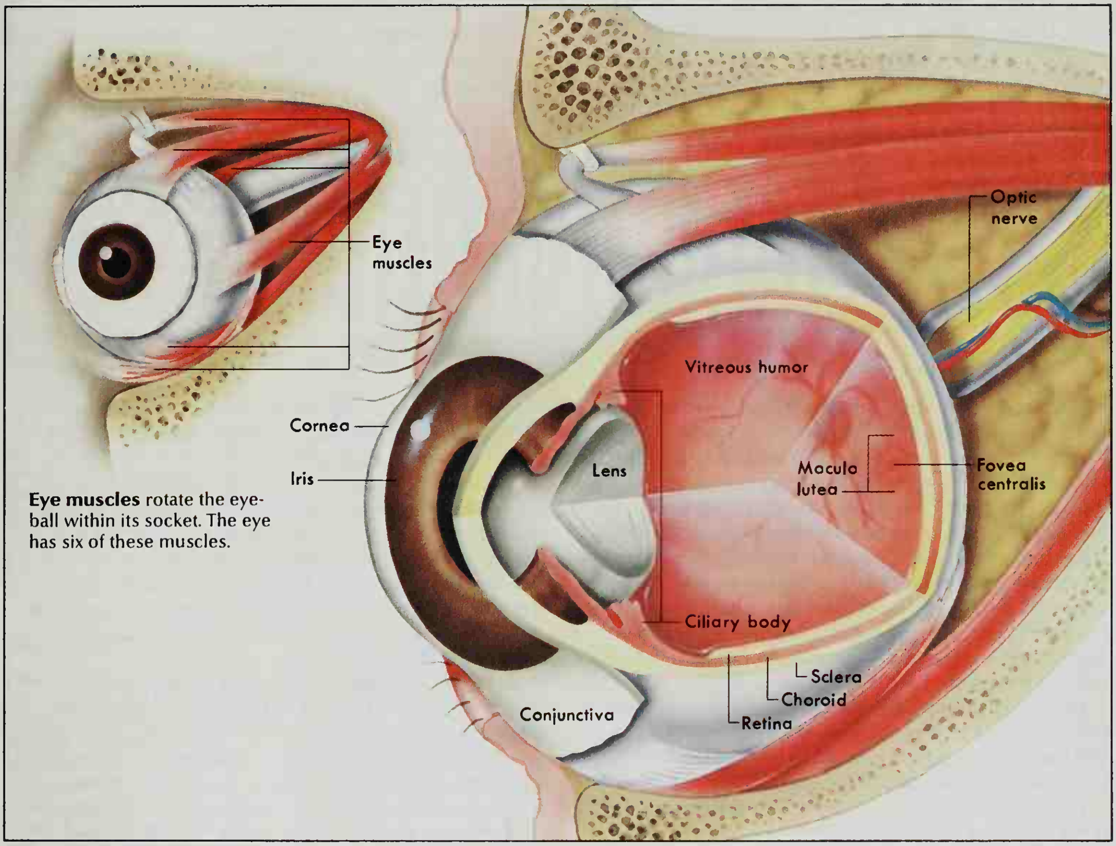
WORLD BOOK illustration by Charles Wellek

The human eyes produce tears by means of the *lacrimal glands,* one of which lies above each eyeball. The tears wash the eye and then flow into canals that lead to the *lacrimal sac.* From this sac, the tears drain through a passage into the nose.

Morton F. Goldberg, the contributor of this article, is Professor of Ophthalmology and Chairman of the Department of Ophthalmology at the Wilmer Eye Institute of the Johns Hopkins School of Medicine in Baltimore.

Parts of the eye The visible parts of the eyeball are the white *sclera* and the colored *iris.* A membrane called the *conjunctiva* covers the sclera. The clear *cornea* lies in front of the iris. The *lens* is connected to the *ciliary body.* Inside the eyeball is a clear substance called *vitreous humor.* The *retina,* which underlies the *choroid,* changes light rays into electrical signals. The *optic nerve* carries the signals to the brain. The *fovea centralis,* a pit in the *macula lutea,* is the area of sharpest vision.

WORLD BOOK illustrations by Charles Wellek

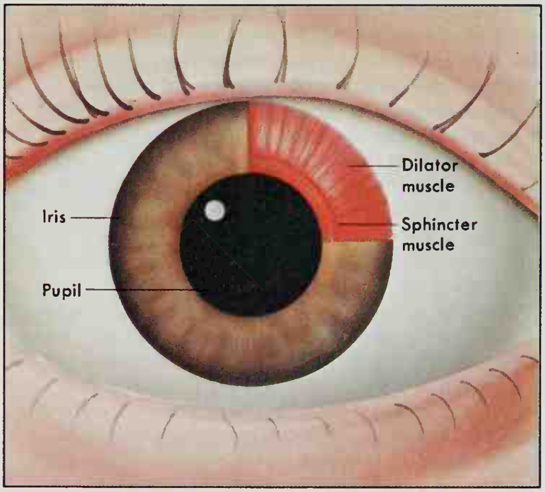


Eye muscles rotate the eyeball within its socket. The eye has six of these muscles.

blue eyes. In addition to giving the iris color, melanin absorbs strong light that might otherwise dazzle the eye or cause blurred vision. Melanin is the same substance that gives skin and hair their color. People called *albinos* have little or no melanin. They have milky-white skin, white hair, and pinkish-gray irises. Their eyes are extremely sensitive to light. Most albinos have very poor vision (see **Albino**).

At the center of the iris is a round opening called the *pupil,* which looks like a black circle. The pupil regulates the amount of light that enters the eye. Two muscles in the iris automatically adjust the size of the pupil to the level of light. In dim light, the *dilator muscle* enlarges the pupil. As much light as possible can then enter the eye. In bright light, the *sphincter muscle* makes the pupil smaller, which prevents too much light from entering the eye. The pupil also becomes smaller when the eye looks at a nearby object, thus bringing the image into sharp focus.

The ciliary body encircles the iris. It is connected by strong fibers to the *crystalline lens,* which lies directly behind the iris. The lens is a flexible structure about the size and shape of an aspirin tablet. Like the cornea, the lens is transparent because it has no blood vessels and



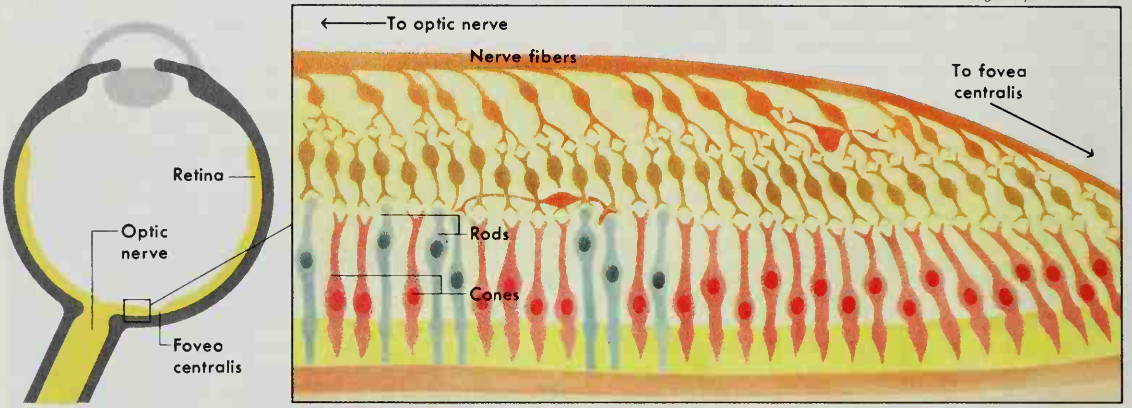
WORLD BOOK illustration by Charles Wellek

The iris has a round opening called the *pupil,* which regulates the amount of light that enters the eye. In dim light, the *dilator muscle* pulls the pupil open wider. In bright light, the *sphincter muscle* tightens around the pupil and makes it smaller.

Structure of the retina

The retina has cells called *rods* and *cones,* which absorb light rays and change them into electrical signals. There are more cones than rods in the central area of the retina. The cones are concentrated in the fovea centralis. Nerve fibers attached to the rods and cones join to form the optic nerve.

WORLD BOOK diagram by Charles Wellek



is relatively dehydrated. The muscles of the ciliary body make constant adjustments in the shape of the lens. These adjustments produce a sharp visual image at all times as the eye shifts focus between nearby and distant objects. The ciliary body also produces a clear, watery fluid called *aqueous humor.* This fluid nourishes and lubricates the cornea and the lens, and it fills the area between them. The ciliary body produces aqueous humor continuously. The old fluid flows into a drainage system at a spongy, circular groove where the cornea and the sclera meet. It then travels through the veins of the eyeball into the veins of the neck.

The choroid forms the back of the uveal tract. It looks and feels like a blotter soaked with black ink. The choroid has many blood vessels. Blood from the choroid nourishes the outer part of the retina.

The retina makes up the innermost layer of the wall of the eyeball. It is about as fragile as a piece of wet tissue paper. Light-sensitive cells in the retina absorb light rays and change them into electrical signals. There are two types of these light-sensitive cells—*rods* and *cones.* The cells are named for their shape. The retina has about 120 million rods and about 6 million cones.

Bits of *pigment* (colored material) in the rods and cones absorb even the smallest particle of light that strikes the retina. The pigment in the rods is called *rhodopsin* or *visual purple.* It enables the eye to see shades of gray and to see in dim light. There are three types of pigment in the cones. They enable the eye to see colors and to see sharp images in bright light. *Cyanolabe* absorbs blue light. *Chlorolabe* absorbs green light. *Erythrolabe* absorbs red light. These pigments enable us to distinguish more than 200 colors.

Near the center of the retina is a round area called the *macula lutea* or *macula.* The macula consists chiefly of cones. It produces a sharp image of scenes at which the eyes are directly aimed, especially in bright light. The rest of the retina provides *peripheral vision*—that is, it enables the eyes to see objects to the side while looking straight ahead. Most of the rods lie in this part of the retina. Because rods are more sensitive in the dark than cones, faint objects often can be seen more clearly if the eyes are not aimed directly at them. For example, looking to the side of a dim star makes its image fall on the part of the retina that has the most rods and provides the best vision in dim light.

Nerve fibers attached to the rods and cones join at the center of the retina and form the *optic nerve.* This nerve consists of about a million fibers. It serves as a flexible cable that connects the eyeball to the brain. In fact, the optic nerve and the retina are actually extensions of the brain. The optic nerve carries the electrical signals produced in the retina to the brain, which interprets them as visual images.

The point where the optic nerve enters the eye is known as the *blind spot.* It has no rods or cones and therefore cannot respond to light. Normally, a person does not notice the blind spot because it covers such a small area and the eyes make so many quick movements. In addition, anything the blind spot of one eye cannot see is seen by the other eye. See **Blind spot.**

How we see

Focusing. Light rays that enter the eye must come to a point on the retina for a clear visual image to form. However, the light rays that objects reflect or give off do not naturally move toward one another. Instead, they either spread out or travel almost parallel. The focusing parts of the eye—the cornea and the lens—bend the rays toward one another. The cornea provides most of the *refracting* (bending) power of the eye. After light rays pass through the cornea, they travel through the aqueous humor and the pupil to the lens. The lens bends the rays even closer together before they go through the vitreous humor and strike the retina. Light rays from objects at which the eyes are aimed come together at the *fovea centralis,* a tiny pit in the center of the macula. It is the area of sharpest vision. Light rays from objects to the sides strike other areas of the retina.

The refracting power of the lens changes constantly as the eye shifts focus between nearby objects and distant ones. Light rays from nearby objects spread out, and those from distant objects travel nearly parallel. Therefore, the lens must provide greater bending power for the light rays from nearby objects to come together. This additional power is produced by a proc-

ess called *accommodation.* In this process, one of the muscles of the ciliary body contracts, thereby relaxing the fibers that connect the ciliary body to the lens. As a result, the lens becomes rounder and thicker and thus more powerful. When the eye looks at distant objects, the muscle of the ciliary body relaxes. This action tightens the fibers that are connected to the lens, and the lens becomes flatter. For this reason, the eye cannot form a sharp image of a nearby object and a distant one at the same time.

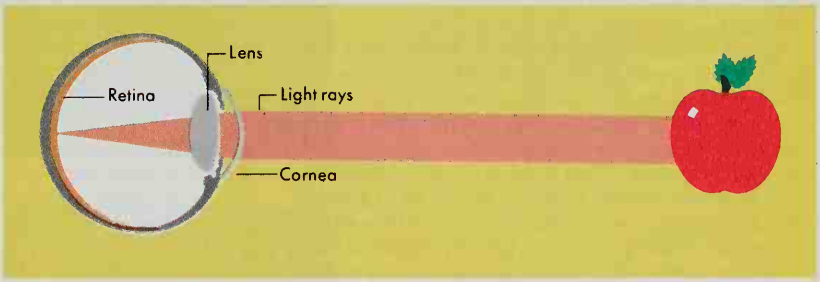
Depth perception is the ability to judge distance and to tell the thickness of objects. The lens system of the eye, like the lens of a camera, reverses images. Thus, the images that form on the retina are much like those produced on film in a camera. The images are upside down and reversed left to right. They are also flat, as in a photograph. However, the brain interprets the images as they really are. The ability of the brain to interpret retinal images right-side up, unreversed, and in depth comes from experience that begins at a person's birth.

The optic nerves from the two eyes meet at the base of the brain at a point called the *optic chiasm.* At the optic chiasm, half the nerve fibers from each eye cross over and join the fibers from the other eye. Each side of the brain receives visual messages from both eyes. The nerve fibers from the right half of each eye enter the right side of the brain. These fibers carry visual messages from objects that are to a person's left. The

How the eye focuses

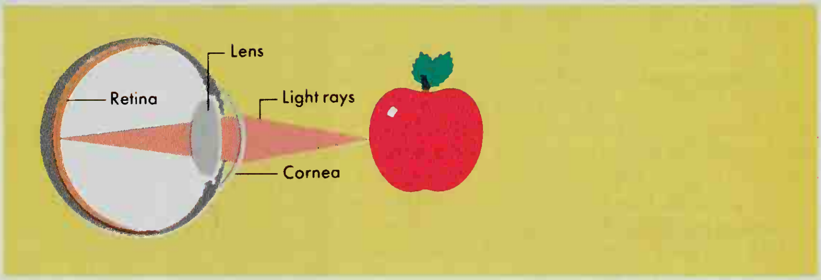
Distance vision

Distant objects reflect or give off light rays that are nearly parallel as they enter the eye. The cornea and the lens bend the rays toward one another, which makes them come together on the retina and form a clear visual image.



Near vision

Nearby objects reflect or give off light rays that are spreading out as they enter the eye. Greater bending power is thus needed to bring these rays together. The lens provides this power by becoming rounder and thicker in a process called *accommodation.*

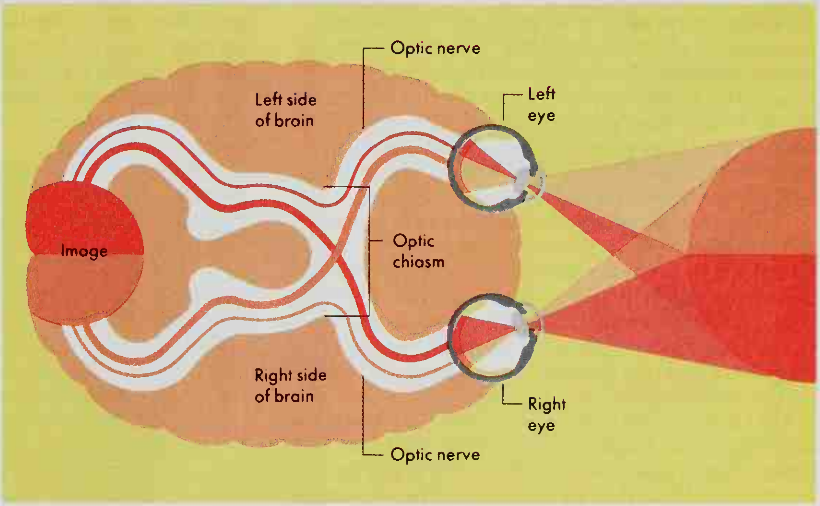


WORLD BOOK diagrams by Linda Kinnaman

How we see in depth

WORLD BOOK diagram

Depth perception is the ability to judge distance and to tell the thickness of objects. Because the eyes are set slightly apart, each one sees objects from a slightly different angle. As a result, each eye sends a slightly different message to the brain. Some of the nerve fibers from each eye cross over at the *optic chiasm.* Each side of the brain thus receives visual messages from both eyes. The brain puts the images together and so provides depth perception.



nerve fibers from the left half of each eye enter the left side of the brain. These fibers carry visual messages from objects that are to a person's right. Thus, if one side of the brain becomes damaged, the opposite side of a person's field of vision may be reduced. Such damage may occur as a result of a stroke, injury, or tumor.

The eyes are about 2 $\frac{1}{2}$ inches (6.4 centimeters) apart from center to center. For this reason, each eye sees things from a slightly different angle and sends slightly different messages to the brain. The difference can be demonstrated by focusing on a nearby object first with one eye closed and then with the other eye closed. The image seen with each eye is slightly different. The brain puts the images together and thus provides depth perception, also called *stereoscopic vision* or *three-dimensional vision.* The image formed by the brain has thickness and shape, and the brain can judge the distance of the object.

Normal depth perception requires that the eyes work together in a process called *binocular vision* or *fusion.* In this process, the eye muscles move the eyes so that light rays from an object fall at a corresponding point on each retina. When viewing objects close up, the eyes turn slightly inward. When viewing distant objects, the eyes are almost parallel. If images do not fall at a corresponding point on each retina, they will be blurred or be seen as double, or the brain will ignore one of them.

In most people, visual messages are stronger in one eye and on one side of the brain than the other. Most people are "right-eyed" or "left-eyed," just as they are right-handed or left-handed. For example, they favor one eye or the other when aiming a camera or a rifle.

Adaptation to light and dark is partly controlled by the pupil. In strong light, the pupil may become as small as a pinhead and so prevent the eye from being damaged or dazzled by too much light. In the dark, it can get almost as large as the entire iris, thus letting in as much light as possible. However, the most important part of adaptation to light and dark occurs in the retina.

Light rays are absorbed by pigments in the retina's rods and cones. The pigments consist of protein and vitamin A. Vitamin A helps give the pigments their color. The color enables the pigments to absorb light. Light changes the chemical structure of the vitamin A and bleaches out the color in the pigments. This process generates an electrical signal that the optic nerve transmits to the brain. After the pigments have been bleached, the vitamin A moves into a part of the retina known as the *retinal pigmented epithelium* (RPE). The vitamin regains its original chemical structure in the RPE and then returns to the rods and cones. There, it joins with protein molecules and forms new pigments.

The renewal of rhodopsin—the pigment that enables the eye to see in dim light—occurs largely in the dark. Immediately after being exposed to bright light, the eyes cannot see well in dim light because of the bleached rhodopsin. It takes about 10 to 30 minutes for rhodopsin to be renewed, depending on how much was bleached. During this time, the eyes become accustomed to the dark.

The cone pigments, which provide sharp vision in bright light, take less time than rhodopsin to be renewed. The eyes become accustomed to bright light much quicker than they do to darkness. The adaptation from darkness to light depends largely on changes in the retina's nerve cells.

Defects of the eye

Defects of the eye are among the most common of all physical disorders. Certain defects cannot be cured, but vision can be improved by means of eyeglasses, contact lenses, or surgery. The most common defects of the eye include (1) nearsightedness, (2) farsightedness, (3) astigmatism, (4) strabismus, and (5) color blindness. A type of surgery called *LASIK* (*la*ser *in situ* *k*eratomileusis) can correct nearsightedness, farsightedness, and astigmatism. In this surgery, a laser is used to reshape the cornea.

Nearsightedness, also called *myopia,* is characterized by blurred distance vision, though near vision remains sharp except in extreme cases. In most cases of nearsightedness, the eyeball is too long from front to back. As a result, light rays from distant objects meet before they reach the retina. When the light rays do strike the retina, they form a blurred image. Eyeglasses or contact lenses that are *concave* bring the light rays together at the retina and correct most cases of nearsightedness. Concave lenses are thinner in the middle than at the edges. See **Nearsightedness.**

Farsightedness, also called *hyperopia,* occurs in most cases because the eyeball is too short from front to back. Unless the lens accommodates, light rays from distant objects reach the retina before they meet, causing a blurred image. The lens of a normal eye remains relatively flat for distance vision and becomes thicker for nearby objects to be brought into focus. In a farsighted eye, however, the lens must also thicken for sharp distance vision. The farsighted eye receives sharp images of distant objects. But the constant use of the muscles of the ciliary body to adjust the shape of the lens may cause eyestrain and headaches. In addition, the lens may not thicken enough for sharp near vision. Glasses or contact lenses that are *convex* correct farsightedness. Convex lenses are thicker in the middle than at the edges. See **Farsightedness.**

Between the ages of 40 to 50, a person's lens begins to harden and to lose its ability to thicken. This condition is called *presbyopia,* and it affects nearly all middle-aged and elderly people. By the time a person is about 60, the lens has almost no flexibility and can barely accommodate. Because of presbyopia, most middle-aged and elderly people need glasses for reading and close work. If they wore glasses before, they may need new glasses with bifocal lenses.

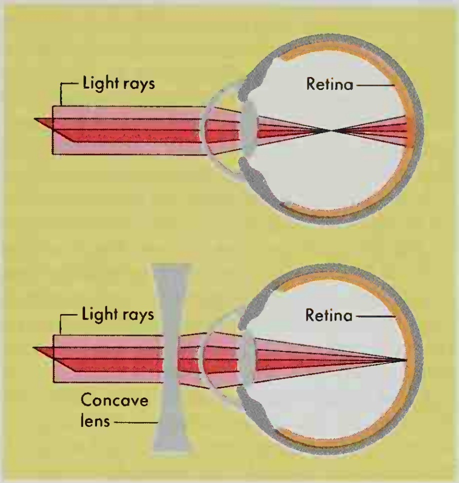
Astigmatism is usually caused by a misshapen cornea. As a result of the abnormal shape, all the light rays from an object do not come together at one point in the eye. Some rays may focus on the retina. But others may meet before they reach the retina, or they may reach the retina before they meet. Most cases of astigmatism produce blurred vision both nearby and at a distance. In mild cases, there may be eyestrain and headaches but fairly sharp vision. Astigmatism may be combined with nearsightedness, farsightedness, or presbyopia. To correct astigmatism, doctors prescribe glasses or contact lenses that have *cylindrical components.* Cylindrical lenses have greater bending power in one axis than in others. See **Astigmatism.**

Defects of the eye

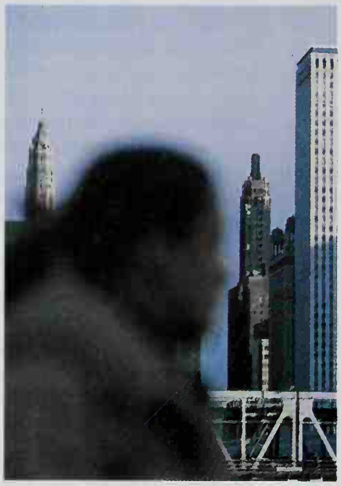
Eye defects are among the most common physical disorders. They include (1) nearsightedness, (2) farsightedness, and (3) astigmatism. These defects cannot usually be cured, but vision can be made normal in most cases by means of eyeglasses or contact lenses, or, occasionally, by surgery.

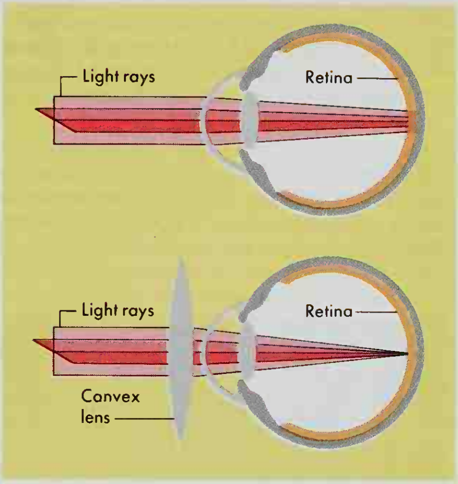
WORLD BOOK photos

WORLD BOOK diagrams by Linda Kinnaman

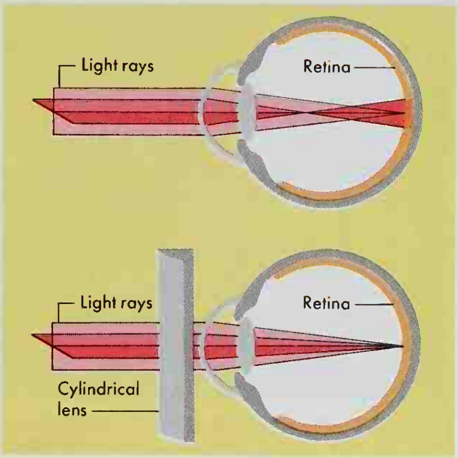


Nearsightedness occurs if light rays from distant objects meet before they reach the retina. In most cases, distance vision is blurred, but near vision is sharp. Glasses or contacts that have *concave lenses* bring the rays together at the retina and correct nearsightedness.





Farsightedness occurs if light rays from distant objects reach the retina before they meet. In many cases, the lens can accommodate enough for sharp distance vision but not sharp near vision. Glasses or contacts that have *convex lenses* correct farsightedness.



Astigmatism results if all the light rays from an object do not come together at one point in the eye. Most cases of astigmatism produce blurred vision both nearby and at a distance. Eyeglasses or contact lenses that have *cylindrical lenses* correct the defect.

Strabismus is a defect in which the eyes are not used together. One of the eyes is *deviated* (turned too far in one direction) all or part of the time. In most cases, the deviated eye is turned either toward the nose, a condition called *cross-eye,* or toward the side, a condition called *walleye.* Strabismus occurs most often in young children. In children with strabismus, each eye sees a different part of a scene and sends a greatly different message to the brain. In most cases, the brain tends to ignore the weaker message—the one from the deviated eye. Blurring or double vision also may occur.

Many cases of strabismus can be corrected if detected early. Strabismus may be treated by means of glasses, eye drops, surgery on the muscles of one or both eyes, or a patch worn for a time over one of the eyes—in most cases, the nondeviated one. Unless strabismus is corrected early, vision in the deviated eye may be permanently reduced. This condition is called *strabismic amblyopia* or *lazy eye.* See **Strabismus.**

Color blindness, also called *color vision deficiency* or *color-defective vision,* refers to difficulty telling colors apart. Very few people are unable to distinguish colors at all. In most cases of color blindness, certain colors are confused with others. For example, a green object may appear brown. Color blindness is caused by abnormalities in the pigments of the retina's cones. Nearly all color blindness is present at birth. More males than females are color blind. The condition cannot be corrected, but it does not get worse. See **Color blindness.**

Diseases of the eye

Disease may affect any part of the eye. Eye diseases cause a great majority of all blindness. Injuries cause the rest. Eye diseases include (1) cataract, (2) glaucoma, (3) diseases of the outer parts, (4) diseases of the sclera, (5) diseases of the cornea, (6) diseases of the uveal tract, (7) diseases of the retina, and (8) diseases of the optic nerve.

Cataract is a condition in which part or all of the lens becomes clouded. The clouded part of the lens is also called a cataract. Severely reduced vision—or even blindness—results if the cloudiness covers a large area, is dense, or is at the center of the lens. However, some cataracts cause little or no loss of vision. Most cataracts result from aging. If a cataract causes enough loss of vision that it interferes greatly with a person's daily activities, the lens is removed by surgery. The patient must then wear strong glasses or contact lenses to see well. In most cases, surgeons replace the diseased lens with a plastic *intraocular lens.* See **Cataract.**

Glaucoma is a disease in which the aqueous humor—the fluid that nourishes the cornea and the lens—does not drain properly. Pressure in the eye increases and, if untreated, destroys the optic nerve. In *primary open-angle glaucoma,* the most common type, vision to the side gradually narrows, and total blindness may eventually result. Primary open-angle glaucoma occurs chiefly in people over 40 years old. It is also called *chronic simple glaucoma.* It goes unnoticed by most people until some vision is lost, though a physician can detect the disease shortly after it develops. Physicians treat most cases of open-angle glaucoma with eye drops, pills, or laser therapy. Such treatments reduce pressure in the eye and so halt damage to the optic nerve. In most cases, patients must use the medicine throughout life and some will require periodic laser treatments. If medicine and laser therapy are not effective, a new drainage channel for the aqueous humor is made or the old channels are surgically reopened.

A type of glaucoma called *primary narrow-angle glaucoma* or *acute glaucoma* may occur suddenly at any age. Its symptoms include pain in the eyes or forehead and seeing halos or rainbows around lights. Immediate surgery or laser treatment may be necessary to prevent blindness. See **Glaucoma.**

Diseases of the outer parts. Various diseases can affect the outer parts of the eye. A *sty* is an infection of one of the sacs from which the eyelashes grow. A sty looks like a pimple on the edge of the eyelid. Sties may be treated by applying a moist, warm cloth and by using prescribed antibiotics. In some cases, pus from a sty may have to be drained by minor surgery. See **Sty.**

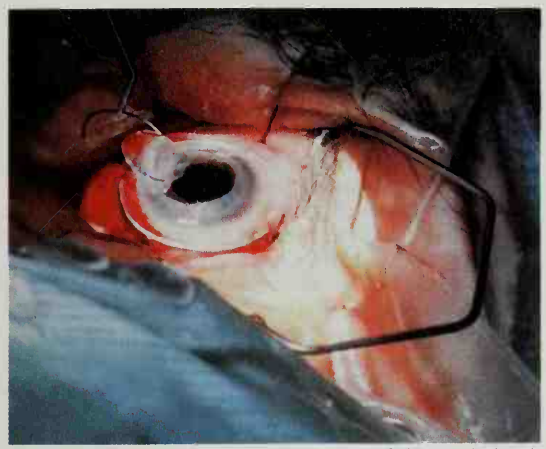
A *chalazion* is a blocked gland along the eyelid. If the gland becomes infected, a lump may form under the lid. The infected gland is treated the same way as a sty. After the infection clears up, the chalazion may be removed by minor surgery.

A disease called *conjunctivitis* is an inflammation of the conjunctiva, the membrane that lines the eyelids and covers part of the eyeball. Some types of conjunctivitis are called *pinkeye.* The disease may be caused by an infection, by an allergy, or by such substances as smoke or smog. The eyes become red and watery, and pus may form. Many types of conjunctivitis are contagious. They are often spread when someone uses the same towel or swims in the same swimming pool as a person who has the disease. Doctors often treat conjunctivitis with eye drops. They also may advise patients to take precautions so as to avoid infecting others. See **Conjunctivitis.**

Disorders of the eye's outer parts

These illustrations show four eye disorders. A *sty* resembles a pimple on the eyelid. A *chalazion* may form a lump under the eyelid. *Conjunctivitis* is an inflammation of the conjunctiva. A *subconjunctival hemorrhage* is a broken blood vessel in the conjunctiva. It is harmless and should clear up in a week or two.

WORLD BOOK illustrations by Charles Wellek



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Surgical implantation of a plastic intraocular lens can restore normal vision in a patient with a cataract. A cataract clouds the eye's lens, causing progressive vision loss. This intraocular lens is being placed in a surgically created hole in the cornea.

A severe form of conjunctivitis called *trachoma* is caused by a microscopic organism. The disease is treated with drugs or surgery or both. Trachoma is a rare disease in the industrialized world, but it is a leading cause of blindness in many less developed countries. See Trachoma.

Diseases of the sclera, the white part of the eye, are relatively uncommon. Inflammation of the sclera is called *scleritis.* Most cases of scleritis are caused by an infection or an allergy. The disease may also be associated with arthritis. Physicians usually treat scleritis with eye drops or pills.

Diseases of the cornea are among the most common eye disorders. The cornea has less protection than any other part of the eyeball. It may be accidentally scratched by an overworn contact lens, a fingernail, or a particle that flies into the eye, and a painful infection can result. Inflammation of the cornea may be caused by the *herpes simplex virus,* the same virus that causes cold sores. Physicians treat infections of the cornea with antibiotics, often in the form of drops or ointments.

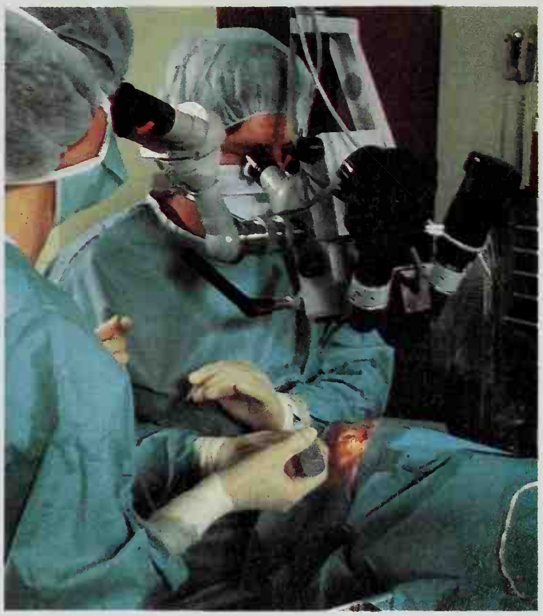
A disease called *keratoconus* leads to a deformed cornea. As the disease progresses, the cornea becomes cone-shaped. In the early stages, keratoconus can be treated with glasses or contact lenses. In severe cases, the cornea may be removed by surgery and replaced with a cornea from a person who recently died. The replacement comes from an agency called an *eye bank* (see Eye bank). This operation is known as a *corneal transplant* or *corneal graft* and is used to treat many disorders that cause diseased corneas.

Diseases of the uveal tract. An inflammation of the uveal tract is called *uveitis.* Such diseases include *iritis,* inflammation of the iris; *cyclitis,* inflammation of the ciliary body; and *choroiditis,* inflammation of the choroid. In many instances, the cause of these diseases cannot be determined. Physicians treat such cases by prescribing medications that reduce the inflammation. The uveal tract may also be attacked by a cancerous tumor called a *melanoma.* Physicians may remove the tumor or the entire eye, or they may use other techniques, such as radiation treatments, to prevent the cancer from spreading.

Diseases of the retina. A number of diseases can damage the retina. One of the most common causes of new cases of blindness among adults is *diabetic retinopathy,* which strikes some people who have diabetes. After many years of diabetes, the blood vessels of the retina may leak, close up, or begin to grow. These conditions may cause blood to enter the vitreous humor, the clear, jellylike fluid inside the eyeball. The blood makes the vitreous *opaque* (nontransparent), causing blindness. In some cases, a major surgical procedure called a *vitrectomy* can remove the blood and restore vision. In another procedure, a narrow beam of light from a laser destroys the abnormal vessels of the retina before blood enters the vitreous.

Diabetic retinopathy—and many other disorders of the eye—can also result in a *detached retina.* In this condition, the retina pulls away from the choroid. A detached retina can be corrected surgically by indenting the wall of the eyeball so that the choroid meets the retina. If this procedure is successful, the retina then remains attached to the choroid. The retina itself is too fragile to be manipulated by surgical instruments, and so it cannot be pushed back to meet the choroid.

One of a group of diseases called *macular degeneration* may affect the macula, the part of the retina responsible for sharp central vision. The patient loses the ability to see objects at which the eyes are directly aimed, though vision to the side remains. Some cases of macular degeneration are inherited. The most common form, called *age-related macular degeneration* (AMD), appears in old age. Special magnifying devices enable some patients to see well enough to read. In addition, laser treatment can prevent or postpone serious vision loss in some patients, provided such treatment begins as soon as visual problems are noticed.



© Bob Hahn, Taurus

Eye surgery is often performed with the aid of a microscope to magnify the small, delicate structures of the eye.

When to consult an eye doctor

Doctors recommend that everyone have an eye examination shortly after birth and at least every few years until the age of 40. Thereafter, the eyes should be examined about once a year or every two years. In addition, the eyes should be examined any time one of the following conditions persists:

1. Blurred vision.
2. Constant rubbing of the eyes.
3. Cross-eye or walleye.
4. Difficulty seeing either nearby objects or distant ones.
5. Double vision.
6. A drooping eyelid.
7. Excessive tearing by the eyes.
8. The feeling of having a particle in one eye or both eyes.
9. Pain in the eyes or brows.
10. Poorer vision in one eye than the other.
11. Redness of the eyes.
12. Seeing flashes of light or spots in front of the eyes.
13. Seeing halos or rainbows around lights.
14. Sensitivity of the eyes to light.
15. Squinting.
16. A white or yellow appearance to the pupil.

A group of diseases called *retinitis pigmentosa* chiefly affects the rods and cones of the retina. One of the first symptoms is *night blindness,* in which a person sees very poorly or not at all in dim light or at night. Many patients lose vision to the side and have only *tunnel vision.* Some gradually become blind. Retinitis pigmentosa is inherited. Vitamin A, taken in high doses under medical supervision, has been shown to slow the progression of the disease.

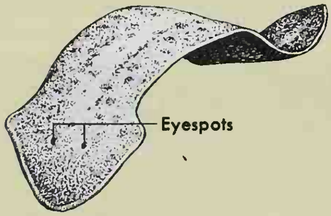
Cancer of the retina is called *retinoblastoma.* In many cases, it is inherited, and a tumor forms in the retina in early childhood. Doctors treat the disease with X rays or drugs. Some patients must have the eye removed.

A blood disease called *sickle cell anemia* damages many parts of the body and may eventually result in death. The disease can cause a condition known as *sickle cell retinopathy.* In this condition, the blood vessels of the retina may clot or may begin to grow and bleed. In many cases, blindness results. Some cases of sickle cell retinopathy can be treated successfully by means of a laser or by eye surgery. See **Sickle cell anemia.**

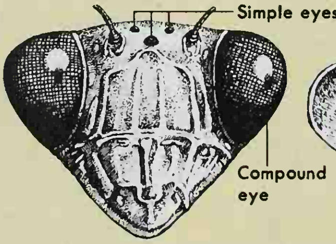
A condition called *retinopathy of prematurity* can occur in some premature infants. Immediately after birth, premature infants are sometimes placed in incubators, which provide warmth and a high level of oxygen. However, the incubator's high oxygen level may contribute to abnormal development of the blood vessels of the retina in some infants. This condition can lead to permanently reduced vision or even blindness. Retinopathy of prematurity has also occurred in some premature babies who have not been given high levels of oxygen. Scientists are not sure what causes such cases. Physicians may use laser treatments or a surgical technique called *cryotherapy* to treat retinopathy of prematurity. Cryotherapy involves freezing part of the eye in order to stop or slow the growth of abnormal tissue in the retina.

Some animal eyes Most animals have organs of some kind that sense light. In some animals, these organs can only tell light from dark. The eyes of certain other animals can see objects clearly even in dim light.

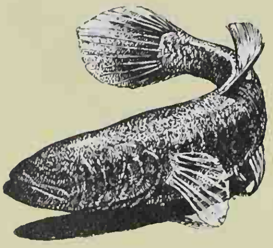
WORLD BOOK illustrations by John Dawson



A flatworm has light-sensitive areas called *eyespots* on its head. These organs distinguish between light and dark but cannot form images.



A praying mantis, like most insects, has *compound eyes* and *simple eyes.* The compound eyes form an image, and the simple eyes respond to light quickly.



A cavefish swims in the dark waters of caves and has sightless eyes. Many animals that live in darkness have eyes that can see little or nothing.

A red-tailed hawk, like most other birds, has a third eyelid called a *nictitating membrane.* Birds close the membrane to blink and the other lids to sleep.

A tarsier, a small mammal of Southeast Asia, has exceptionally large eyes. The eyes provide these animals with excellent vision in dim light.

Diseases of the optic nerve. The optic nerve can be damaged by *optic neuritis* (inflammation of the optic nerve), tumors, infection, and other diseases. Not all diseases of the optic nerve can be treated.

Care of the eye

Preventing eye damage. The most common eye injuries are caused by blows to the eye, by particles that enter the eye, and by chemical burns, explosions, and firearms. Many such injuries can be prevented. For example, safety glasses or goggles protect the eyes from particles that may be thrown from electric saws, grinding wheels, and other power tools. Some athletes also wear safety glasses to prevent eye injuries caused by balls, rackets, hockey pucks, and other sports equipment. In most cases, specks of dust or other particles that enter the eye can be removed by blinking gently or by flushing the eye with water. If the particle does not come out, it should be removed by a physician. A fragment of glass, metal, or wood—or any particle stuck on the cornea—also should be removed by a physician. If chemicals enter the eye, they should be washed out immediately with large amounts of water, and a physician should be consulted at once.

The eyes can also be damaged through improper use of contact lenses, eye makeup, and sun lamps. Infection may develop if contact lenses are not clean before they are inserted in the eyes. The hands also should be clean, and saliva should never be used to moisten the lenses before inserting them. People should not wear contact lenses longer than the time prescribed by the eye doctor. Eye infections also may result from sharing eye makeup or from moistening the cosmetics with saliva to apply them. The light of a sun lamp can cause painful burns of the cornea. Special goggles should be worn when using a sun lamp. No one should ever look directly at the sun, even during an eclipse.

Receiving regular eye examinations. Doctors recommend that everyone have an eye examination shortly after birth and at least every few years until the age of 40. Thereafter, the eyes should be examined about once a year or every two years. Eye examinations may be given by an *optometrist* or an *ophthalmologist*. Optometrists are licensed professionals who test vision and prescribe glasses and contact lenses. Ophthalmologists, also called *oculists,* are physicians who specialize in the eye. They test vision, prescribe glasses and contact lenses, and treat eye diseases by means of medication and surgery. *Opticians* make and sell glasses and contact lenses prescribed by optometrists and ophthalmologists.

One of the most familiar parts of an eye examination tests *visual acuity* (sharpness of vision) at a distance. This test involves reading letters from a chart a certain distance away—usually 20 feet (6 meters). The letters of each line are smaller than those in the line above. A person who can read all the lines that a normal eye can see from 20 feet (6 meters) has normal visual acuity. This vision is expressed as 20/20 (6/6 in the metric system). A higher denominator indicates a visual defect. For example, a person with 20/40 (6/12) vision must be 20 feet (6 meters) from the chart to read all the lines that a normal eye can see from 40 feet (12 meters). Each eye is tested individually, and one eye may have better vision than the other. Optometrists and ophthalmologists also test near vision and side vision.

Ophthalmologists and optometrists also examine the inside of the eye for any sign of disease. By looking through the pupil with various instruments, these specialists can examine the blood vessels of the retina and the fibers of the optic nerve. The condition of these structures may indicate not only an eye disease but also the advance of such diseases as diabetes and high blood pressure. For this reason, doctors also look into the eye as part of a routine physical examination.

Eyes of animals

Most animals have organs of some kind that sense light. The most elementary of these organs are called *eyespots.* Eyespots are light-sensitive areas on the bodies of flatworms, starfish, and certain other *invertebrates* (animals without a backbone). The organs can distinguish between light and dark but cannot form images.

Other invertebrates have true eyes. Most kinds of insects have two large *compound eyes.* These eyes consist of many tiny lenses. Each lens admits light rays from one direction—one bit of the total scene that the insect sees. All the bits combine and form an image. Many adult insects also have three *simple eyes* set in a triangle between the compound eyes. Each simple eye has one lens. The simple eyes do not form images, but they respond to light quickly. Most *crustaceans,* such as lobsters, have two compound eyes, and many species also have a simple eye.

Spiders have only simple eyes. Most spiders have eight eyes. The eyes are arranged so that spiders can distinguish movement as light from a moving object shifts from one eye to the next.

The eyes of most *vertebrates* (animals with a backbone) have a structure similar to that of the human eye. However, the eyes may vary greatly in certain details. For example, many vertebrates that live in total darkness, such as in deep caves, have tiny eyes that can see little or nothing. On the other hand, owls and some other animals that hunt at night have extremely large eyes and pupils, which provide excellent vision in dim light. Cats also have good night vision. A mirrorlike structure in the eye called the *tapetum lucidum* reflects light onto the retina. The structure makes a cat's eyes appear to glow at night when light is reflected off them.

Most birds have three eyelids—an upper lid, a lower lid, and a *nictitating membrane,* which moves sideways. The animals use the nictitating membrane to blink, and they close the upper and lower lids when sleeping. Birds have the best visual acuity of all animals, including human beings. For example, a vulture can see a dead animal on the ground from a height of up to 2 $\frac{1}{2}$ miles (4 kilometers). Morton F. Goldberg

Related articles in *World Book* include:

Disorders of the eye

Astigmatism	Farsightedness	Ophthalmia
Blindness	Glaucoma	Snow blindness
Cataract	Iritis	Strabismus
Color blindness	Nearsightedness	Sty
Conjunctivitis	Nystagmus	Trachoma

Other related articles

Aging (Signs of aging) Artificial eye

Blind spot
Color (How we see color)
Compound eye
Contact lens
Eye bank
Glasses
Laser (Heating)
Lighting
Ophthalmology
Ophthalmoscope
Optical illusion
Optometry
Tears

Outline

I. Parts of the eye
A. The outer parts
B. The sclera and the cornea
C. The uveal tract
D. The retina

II. How we see
A. Focusing
B. Depth perception
C. Adaptation to light and dark

III. Defects of the eye
A. Nearsightedness
B. Farsightedness
C. Astigmatism
D. Strabismus
E. Color blindness

IV. Diseases of the eye
A. Cataract
B. Glaucoma
C. Diseases of the outer parts
D. Diseases of the sclera
E. Diseases of the cornea
F. Diseases of the uveal tract
G. Diseases of the retina
H. Diseases of the optic nerve

V. Care of the eye
A. Preventing eye damage
B. Receiving regular eye examinations

VI. Eyes of animals

Questions

Which parts of the eye focus light rays on the retina?
How do the pigments of the rods and cones differ in their response to light?
What are compound eyes? Simple eyes?
What does the optic nerve do?
What makes the cornea transparent?
What is strabismus? A cataract? Glaucoma?
What part of the eyeball regulates the amount of light that enters the eye?
Why do most middle-aged and elderly people need glasses for reading and close work?
What is diabetic retinopathy?
Why is it impossible for the human eye to form a sharp image of a nearby object and a distant one at the same time?

Additional resources

Level I
Jedrosz, Aleksander. *Eyes.* Troll, 1992.
Lauber, Patricia. *What Do You See and How Do You See It?* Crown, 1994.
Sinclair, Sandra. *Extraordinary Eyes: How Animals See the World.* Dial, 1992.

Level II
Cassel, Michael D., and others. *The Eye Book.* Johns Hopkins, 1998.
Hubel, David H. *Eye, Brain, and Vision.* 1988. Reprint. Scientific Am. Bks., 1998.
Rodieck, R. W. *The First Steps in Seeing.* Sinauer, 1998.

Eye bank is a nonprofit agency through which eyes removed shortly after death are distributed to specially trained surgeons. These surgeons perform an operation called a *corneal transplant* on people who are blind from diseases that cause scarring of the *cornea.* The cornea is the transparent outer layer through which light enters the eye (see **Eye** [Diseases of the cornea]). The operation consists of replacing the central portion of the scarred cornea with clear corneal tissue.

An eye remains suitable for surgery for only a short time after removal from the body. For this reason, it must be sped to the eye bank. A surgeon must remove the donor's eyes within three hours after death and pack them in special containers just above freezing temperature. The container is rushed to an eye bank, where the eyes are carefully examined and tested to determine if they are suitable for surgery. An eye surgeon who has patients waiting for surgery is notified that an eye is available. The surgeon sends a patient to the hospital, and the operation is performed immediately after arrival of the eye.

The first eye bank was formed in 1944 in New York City. Many eye banks have since developed in other cities and countries. People who wish to donate their eyes should register with an eye bank. Prospective donors can then sign legal documents to donate their eyes upon death. If a person has not signed such documents, the nearest relative must give legal permission for removal of the eyes after death. Some donated eyes may be unsuitable for corneal transplantation. But such eyes can be used for study and research. David E. Eifrig

Eyeglasses. See Glasses.

Eyre, Lake. See Lake Eyre.

Ezekiel, Book of, is a book of the Bible named for a Jewish prophet. Ezekiel's ministry lasted from 593 to 572 or 571 B.C. With the prophets Jeremiah and Isaiah, he was one of the major interpreters of the *Babylonian Exile.* The exile was a period that followed the Babylonian conquest of the kingdom of Judah and its capital of Jerusalem in 587 or 586 B.C.

Chapters 1-24 of the book present Ezekiel's prophecies that calamities will strike the people of Jerusalem and Judah as God's punishment for their sins. Chapters 25-32 consist of Ezekiel's prophecies against neighboring nations for defying God's will and rejoicing over the misfortunes of the Israelites. In chapters 33-48, Ezekiel prophesies Israel's restoration and salvation.

Ezekiel was a priest as well as a prophet. He stressed the importance of following religious law and strictly obeying religious forms and ceremonies. In the book, Ezekiel describes many strange visions. For example, chapter 1 includes a vision of God's dazzling throne chariot in the sky. In chapter 37, Ezekiel describes the valley of dry bones. In this vision, the prophet portrays the exiled Israelites as bones coming to life and being transported back to Judah. Eric M. Meyers

See also **Bible** (Books of the Hebrew Bible).

Ezra, Book of, is a book of the Bible. Jewish editions of the Bible combine Ezra with the Book of Nehemiah in a collection of books called the Writings. Ezra is a separate book in Christian Bibles placed in a group called the Historical Books.

The Book of Ezra was written about 400 B.C. It recounts the story of the Jews' return from their exile in Babylonia, which had begun with the Babylonian conquest of the Jews in 587 or 586 B.C. The book also describes the rebuilding of the Temple in Jerusalem after the Babylonians had destroyed the original Temple.

Ezra was a priest and scribe who led a group of exiles back to Jerusalem, probably in 458 B.C., but no later than 397 B.C. He was responsible for a number of religious and social reforms. These reforms included the cancellation of marriages between Jews and non-Jews. Ezra 7:27 to 9:15 is known as Ezra's memoirs, because the passage is written in a form similar to a diary. Ezra 7-10 summarizes his achievements. Eric M. Meyers

See also **Bible** (Books of the Hebrew Bible).